

AD-A183 993

LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR PHASE 1 AND
PARTIAL PHASE 2 VOLUM (U) FNC CORP MINNEAPOLIS MINN
NORTHERN ORDNANCE DIV R RATHE ET AL APR 87

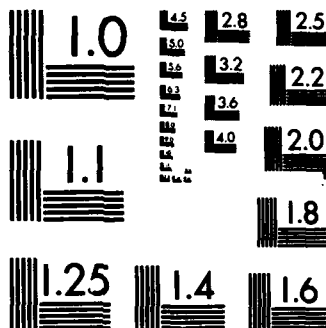
27

UNCLASSIFIED

FMC-E-3041-VOL-D3-PT-1 DAAA21-86-C-0047

F/G 19/6

NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

2

DTIC FILE COPY

Lightweight Towed Howitzer Demonstrator

Final Report

Volume D3 - Part I

Structural Analysis of System

April 1987

DTIC
ELECTE
SEP 03 1987
S D
G D

Contract Number DAAA21-86-C-0047

FMC CORPORATION
Northern Ordnance Division
4800 East River Road
Minneapolis, Minnesota 55421

DISTRIBUTION STATEMENT A
Approved for public release
Distribution Unlimited

"THE VIEWS, OPINIONS, AND/OR FINDINGS CONTAINED IN THIS REPORT ARE THOSE OF THE AUTHOR(S) AND SHOULD NOT BE CONSTRUED AS AN OFFICIAL DEPARTMENT OF THE ARMY POSITION, POLICY OR DECISION, UNLESS SO DESIGNATED BY OTHER DOCUMENTATION."

87 9 1 244

AD-A183 993

DISCLAIMER NOTICE

**THIS DOCUMENT IS BEST QUALITY
PRACTICABLE. THE COPY FURNISHED
TO DTIC CONTAINED A SIGNIFICANT
NUMBER OF PAGES WHICH DO NOT
REPRODUCE LEGIBLY.**

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

| REPORT DOCUMENTATION PAGE | | READ INSTRUCTIONS BEFORE COMPLETING FORM |
|---|-----------------------|---|
| 1. REPORT NUMBER | 2. GOVT ACCESSION NO. | 3. RECIPIENT'S CATALOG NUMBER |
| | AD-A183993 | |
| 4. TITLE (and Subtitle) Final report for the Lightweight Towed Howitzer Demonstrator | | 5. TYPE OF REPORT & PERIOD COVERED Final: 20 December 1985 - 13 March 1987 |
| | | 6. PERFORMING ORG. REPORT NUMBER E-3041 |
| 7. AUTHOR(s) Robert Rathe, FMC Program Manager Bart Anderson, FMC Project Manager | | 8. CONTRACT OR GRANT NUMBER(s) DAAA21-86-C-0047 |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS FMC CORPORATION, Northern Ordnance Division 4800 East River Road Minneapolis MN 55421 | | 10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Item 0001 LTHD Phase I and Partial Phase II |
| 11. CONTROLLING OFFICE NAME AND ADDRESS AMCCOM AMSMC-PCW-A(D) Dover NJ 07801-5001 | | 12. REPORT DATE April 1987 |
| | | 13. NUMBER OF PAGES 4,856 |
| 14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) AMCCOM AMSMC-FSA-F Dover NJ 07801-5001 | | 15. SECURITY CLASS. (of this report) Unclassified |
| | | 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE N/A |
| 16. DISTRIBUTION STATEMENT (of this Report) Approved for public release, distribution unlimited. | | |
| 17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report) Same as Block 16. | | |
| 18. SUPPLEMENTARY NOTES None | | |
| 19. KEY WORDS (Continue on reverse side if necessary and identify by block number) 155mm towed gun howitzer, advanced weapons, composite cradle, composite hydraulic actuators, composite trails, field artillery weapon, firing stability analysis, howitzers, hydraulic control valves with force feedback, hydraulic joystick control of gun direction, hydraulic inertial rammer, hydraulic opening breech, hydraulic primer autoloader, lightweight towed howitzer demonstrator (LTHD) load out of battery howitzer, mortar howitzer, recoil energy recovery, recoil mechanism, using metal matrix composites, titanium muzzle brake, titanium platform, titanium spade, titanium walking beams, thermal stability, towing stability analysis, unconventional weapons, and weight reduction of artillery | | |
| 20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The LTHD (Lightweight Towed Howitzer Demonstrator) was to be a 9,000 lb equivalent to the M198, transportable via Blackhawk helicopter, with reduced emplacement time using fewer personnel. The FMC design achieved weight reduction via a mortar-like configuration, composites structure, and hydraulic actuators. Recovery of power from the recoil system, in turn, facilitated crew reduction via hydraulic emplacement, four-way joystick tube lay, and power ramming. FMC completed Concept Development (Ph I) and two-thirds of Detailed Design (Ph II) prior to funds running out. <i>Keywords:</i> | | |

DD FORM 1 JAN 73 1473

EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

TABLE OF CONTENTS

D3/050

| Vol/Sec | Description |
|---------|--|
| D3 | Structural Analysis of System |
| | PART I |
| D3/050 | Table of Contents |
| D3/100 | Structural Analysis of System |
| D3/110 | CEL Memo: October 3, 1986 |
| D3/120 | o Plots from CEL |
| D3/130 | CEL Memo: December 19, 1986 |
| D3/140 | CEL Memo: December 22, 1986 |
| D3/150 | CEL Memo: December 29, 1986 |
| D3/160 | CEL Memo: December 29, 1986 (Progress) |
| D3/170 | CEL Memo: December 30, 1986 |
| D3/180 | CEL Memo: January 7, 1987 |
| D3/190 | CEL Memo: January 8, 1987 |
| | PART II |
| D3/200 | CEL Memo: January 26, 1987 |
| D3/210 | CEL Memo: January 28, 1987 |
| D3/220 | CEL Memo: February 12, 1987 |



| | |
|--------------------|--|
| Accession For | |
| NTIS CRA&I | <input checked="checked" type="checkbox"/> |
| DTIC TAB | <input type="checkbox"/> |
| Unannounced | <input type="checkbox"/> |
| Justification | |
| By | |
| Distribution/ | |
| Availability Codes | |
| Dist | Avail and/or Special |
| A-1 | 25 mg |

D3/100

STRUCTURAL ANALYSIS OF SYSTEM

PART NUMBER(S):
(NOT APPLICABLE)

DESCRIPTION:

STRUCTURAL ANALYSIS OF SYSTEM

STATUS:

The howitzer system consists of several major structural elements including the gimbal, platform, spade, trails, gun tube, and cradle. Also included are the major interconnections that tie the major structures together.

The goal of the structural analysis was to predict the forces exerted on the major components for the dynamic firing forces of recoil and rifling torque. This information would be employed by the component designers. Therefore, it was important that the dynamics of the structure be modeled correctly. Secondary goals were to predict approximate stresses and the important deflections (e.g. barrel recoil and lift, trail lift, etc.) The model should be formulated so that it may serve as an iterative tool that could be changed easily to reflect design changes or alternative designs.

The analysis was done for proof (limit) load cases which consisted of a simultaneous recoil (79,000#) and rifling torque (42,000 ft-#) loads. These were transient (dynamic) input as forces vs time. A static case was also processed to check the validity of the transient cases and to determine the amplification/deamplification effects. Transportation loads were not considered. Since it was not obvious which orientation was most severe, the model was processed for four orientations consisting of 0° and 72° elevation and 0° and 22.5° traverse. The structural analysis was conducted at CEL. This ANSYS model soon became too large and unwieldy to support design iterations. NOD's function was to provide input to the analysis and to audit modeling and results techniques. In all, four transient and one static cases were processed. A log of reports and memos is given on [D3/I/100 pg 5].

The finite element model description will be limited to major items. These include:

1. The model represents the howitzer geometry as was true of the October - November time frame.

AUTHOR:
Larry Libhardt

2. The ANSYS FEM model includes:
 - a. Platform (quite detailed)
 - b. Gimbal (quite detailed)
 - c. Spade (quite detailed)
 - d. Trail (approximate)
 - e. Cradle (very approximate)
 - f. Barrel (approximate)
 - g. Cables approximate)
 - h. Interconnections (approximate)

These are represented by a few thousand plate and beam elements. Major inertia affects are modeled as mass elements.

3. Rifling torque was input equally to the barrel at both front and rear manifolds locations. Recoil force was applied to the front manifold location only.
4. Total model weight was about 8,100# (a little low). Rotational inertia effects were also included but are probably low also.
5. The model was restrained at the spade rigidly (to represent "hard" soil conditions). Soft springs were attached to the front of the trails to give stability.
6. Numerous geometry plots are contained in the memos. Particularly relevant memos for geometry and assumption information are:
 - a. The Dec. 19, 1986 memo. [D3/I/130]
 - b. The Dec. 22, 1986 memo. [D3/I/140]
 - c. The Jan. 7, 1987 memo. [D3/I/180]
7. The model was good for predicting dynamic stresses in the gimbal and platform and key deflections. It was less useful for other information required (e.g. forces on major components). It is necessary to select time(s) to predict stresses.

Results of the analysis are numerous and include:

1. Von Mises stress plots of the platform, gimbal and spade (at a particular time).
2. Displacement of key locations (as a function of time).

The reader should review the major reports for details of results. A report exists for each of the four transient analyses and the static analysis. There is also a summary of results for the four

orientations in the January 26, 1987 memo [D3/II/200]. The results indicate that stress levels and deflections appear reasonable for the design. Unfortunately forces for the major components were not obtained. The static analysis verified the dynamic analyses and indicated that deamplification was occurring (i.e. dynamic stress less than static stress).

Further analysis was planned to update the model to the latest configuration and to process for the worst orientation (22.5 traverse and 72° elevation). The trails, cradle and platform/gimbal interface would require the most model updating.

LOG - ORTLOFF REPORTS/MEMOS - LTHD

| | <u>DATE</u> | <u>TITLE</u> | <u>FIGURES</u> |
|----|-------------|---|----------------|
| A | 10-3-86 | Summary of Progress | None |
| 1 | 11-25-86 | Static-Comp. Cradle-proof load | 1-81 |
| 2 | 12-8-86 | Static-Comp. Cradle-proof load | 82-143 |
| 3 | 12-16-86 | Element-Node-Comp Cradle | 144-192 |
| 4 | 12-17-86 | Stress in Plat + Gimbal | 193-272 |
| | | Dynamic 0° - 0° | |
| 4A | 12-19-86 | Progress Report: 12-5 to 12-18 | None |
| 5 | 12-22-86 | Request for Infor: Description of FEM - Thermal + Moisture Loads | 264A-269 |
| 6 | 12-29-86 | Stress for 0° - 72° | 270 - 384 |
| 6A | 12-29-86 | Progress Report to 12-28 | None |
| 7 | 12-30-86 | Response to Color Graphic | Misc |
| 8 | 1-7-87 | Delivery of Requested Material | Misc |
| 9 | 1-8-87 | Stress/Stability 22.5 - 0° | 385-466 |
| 10 | 1-14-87 | Est. of Thermal Expansion-Cradle | 467-496 |
| 11 | 1-26-87 | Stress/Stability 22.5 - 72° | 497-601 |
| 12 | 1-28-87 | Remaining Tasks | None |
| 13 | 2-12-87 | Static Analysis (22.5° and 72°) | 602-623 |

D3/110

CEL MEMO: OCTOBER 3, 1986

REC'D 10/21/86

Jim → Larry → Dave L. → Jim

FMC Central Engineering Laboratories
Santa Clara

✓
10/21/86

Interoffice

To R. Rathe

From C. R. Ortloff

Subject SUMMARY OF CEL/NORTHERN ORDNANCE PROGRESS
ON THE LWHD PHASE II LWHD PROJECT

Date October 3, 1986

cc J. Alexander
A. Amberg
B. Anderson
J. Ries
E. Thuse
B. Zierwick
P. Carroll

This memo summarizes the phone conversation (CRO to RR) made on 10/5, and incorporates additional "state of the LWHD" commentary:

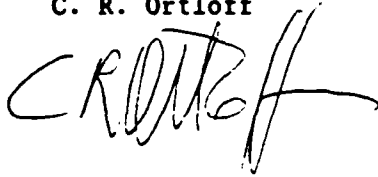
- o A P.O. has been issued for the initial \$20K of AM analysis work; a follow-on P.O. for the full amount is to be issued shortly. A P.O. for CEL materials work will be issued separately to MEL in C.C. Chen's name. The total to CEL is on the order of \$165K.
- o The CEL FE model has been modified to resemble closely the NOD scale model. Because no final detailed drawings of any LWHD part have been received to date, calculations are proceeding with the "best available" configuration represented by the scale model. These calculations have to date uncovered high dynamic stress areas which give insight into the types of materials that must be used in certain zones of the LWHD. Because the FE model is evolving (as unnecessary weight is pared away from the structure and the stress consequences examined) it is providing insight into how to create a composite structure that meets weight and strength requirements under dynamic loading conditions. Some of these recommendations have already worked themselves into modifications of the NOD design (viz., the aluminum platform base plate segment) while other suggestions are being considered for incorporation. Since the original aluminum honeycomb core area of the platform is viewed negatively by ARDEC and is a "last resort" construction method for the lower platform, it is hoped that some of the suggestions made at the last CEL/NOD meeting (sketches left with B. Zierwick) as to how to construct the lower to upper platform region will be incorporated into the next design iteration. These "suggestions" are backed up by many hours of FE calculations to prove their worth in creating a safe, weight efficient structural design.

CRO/01/861003

- o Since the NOD version of the LWHD is based on functionality, some modification of the model should be anticipated as the weight/stress considerations assume a greater role. At present, I have an 1,800 lbf requirement for the structure (excepting the slide tube); the present FE model (for the same parts) shows a weight of 2,300 lbf with safe stress levels. This weight can be reduced somewhat with further design iterations. In short, the CEL and NOD designs are close, and as the CEL design recommendations are further incorporated, our "functional" and "stress-weight" designs will coalesce. You (RR) indicated that more weight will be made available to the structure as the hydraulics is simplified - this will lessen the need to remove more material and thus create hard-to-manufacture "sculptured" shapes. I believe we are very close to a workable design.
- o The CPU time per run has been reduced to about 3.2 CPU hrs. by new wave fronting techniques - this permits design iterations to be performed rapidly as new considerations arise.
- o A FE model has been created with a rotated (22.5°) gimbal that resembles the model gimbal shape. I am retaining the slightly curved sideplates as they are much stronger torsionally under firing torque loads than flat plates. When the slide tube drawing is ready, a separate file can be made and appended to the main FE model at any QE angle so as to compute forces, deflections and stresses at any firing position with these models the 15 load cases can be calculated rapidly.
- o Wing Cheng will be aiding me shortly in the trail-wheel assembly design (when this drawing becomes available). We will use Don Cronquist's road obstacle loads generated in Phase I to help define the loads on the structure. As Wing has helped develop the filament wound structure optimizer model, his work will be of importance in designing lightweight trails.
- o I have run FE calculations of stress distributions in the LWHD with the trail spades "free". There is a lot of rocking motion, as might be expected, and some new stress highs within the structure (which can be dealt with by local thickening of gimbal parts). Stress in the gimbal bearing is high and this reinforces my idea to use a cup-cone lower platform-gimbal connection for extra safety margin if the lower bearing should fail.

- 4
- o The new dynamic load conditions (proof-loads) have been written into a file for incorporation into all new FE calculations. It is expected that some yielding will occur locally as a result of this "once-only" load. The regular load cases will still be the basis for the design, however.
 - o The FE model has had additions to allow for force predictions necessary for "free body" diagram force-time histories to be generated. At the very least, one can work with the stress distributions and part geometry to estimate the forces that produce the stresses.
 - o It appears that a cooperative effort between CEL and NOD is evolving along with the LWHD design. This project will succeed if we make a special effort to understand each other's concerns.
 - o At present, we are probably behind schedule in all design areas. This is understandable based on recent changes forced by ARDEC on the LWHD design. With these out of the way, we can now begin the "optimization" process.

C. R. Ortloff



D3/120

PLOTS FROM CEL

LTHD Ortloff

Note: Not sure
if these came
with menu?

OCT 30 1986

9-31-14

PLOT NO. 1

PREP7 ELEMENTS

XU=1

YU=1

ZU=1

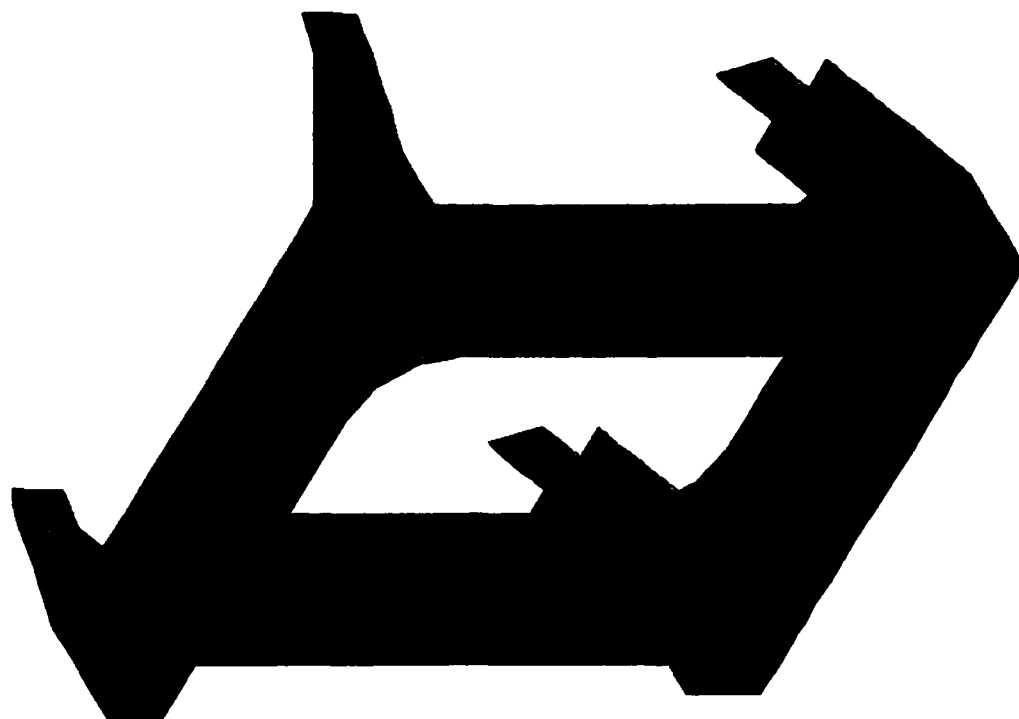
DIST=34.2

XF=1.93

YF=24.9

ZF=-4.51

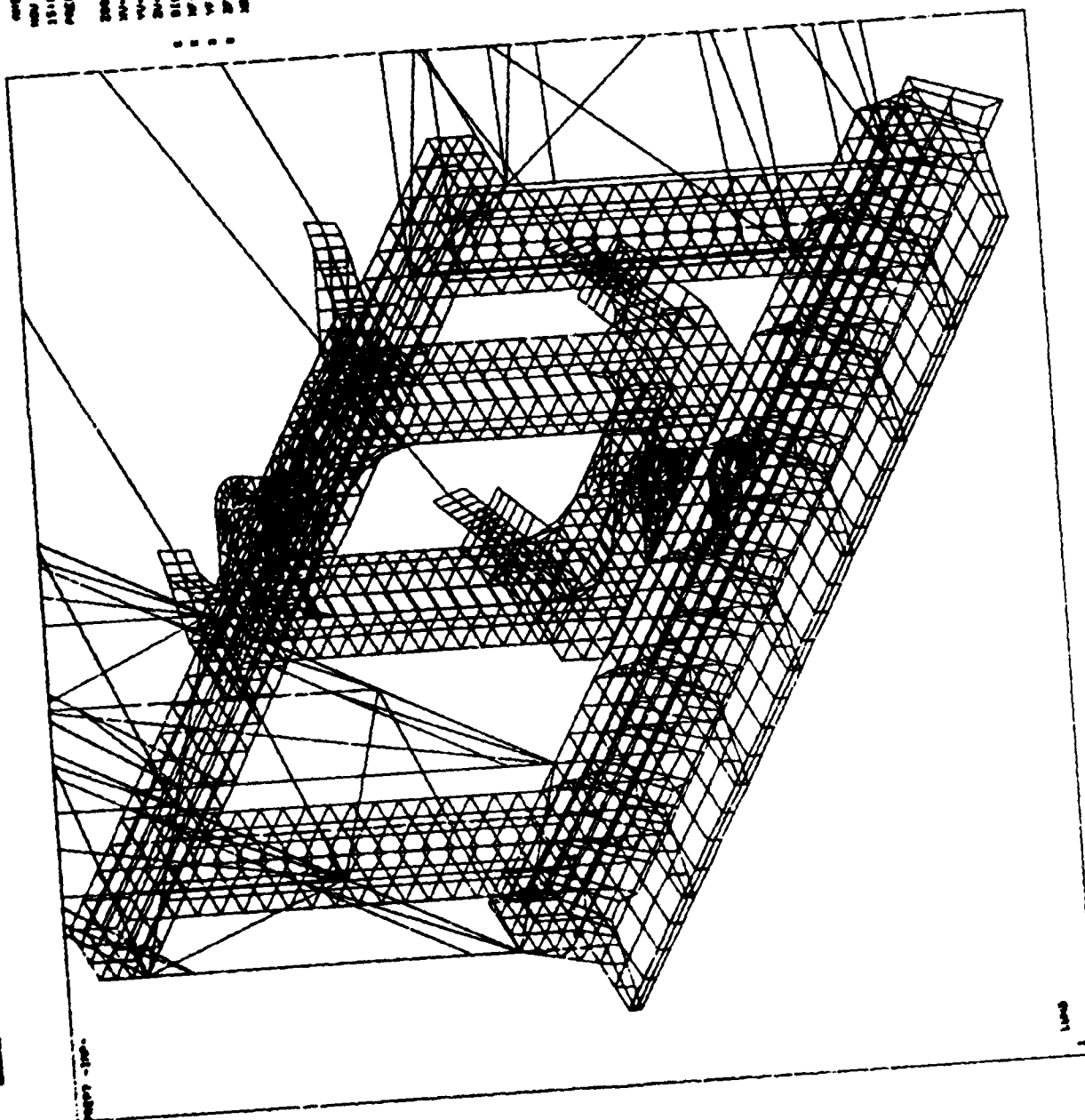
HIDDEN



1 LTHD - GIMBALL DESIGN ANALYSIS (10-27-86 M.W.C.)

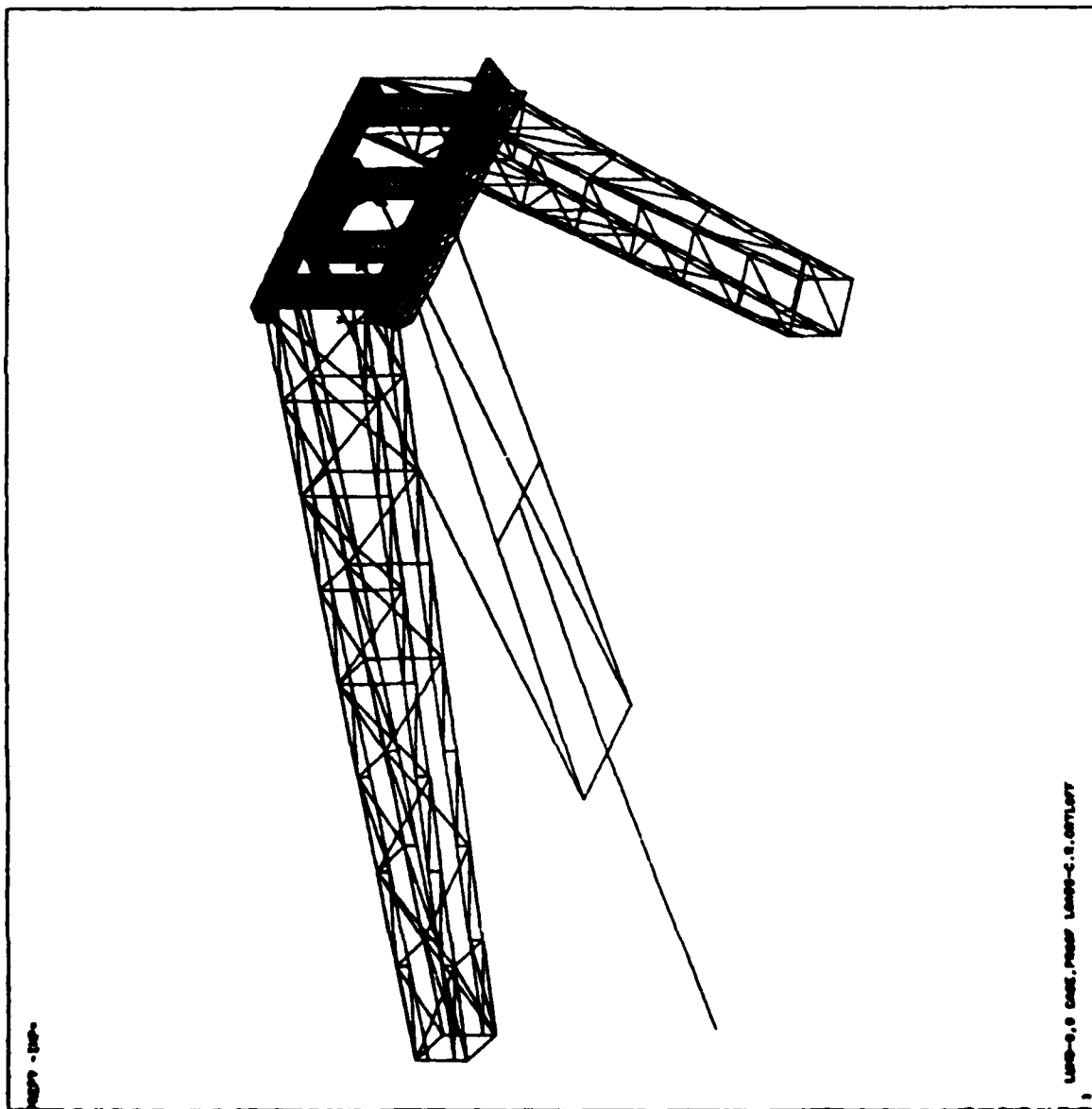
PAGE 4.28
 NOV 19 1966
 15:07:19
 PAGE 4.28

2000
1990
1980
1970
1960
1950
1940
1930
1920
1910
1900



10000 4.00
 10000 24.1000
 0100100
 10000 0.0000000

10000
 10000-1
 10000-1
 10000-1
 0100100
 10000-1
 10000-1
 10000-1
 10000-1

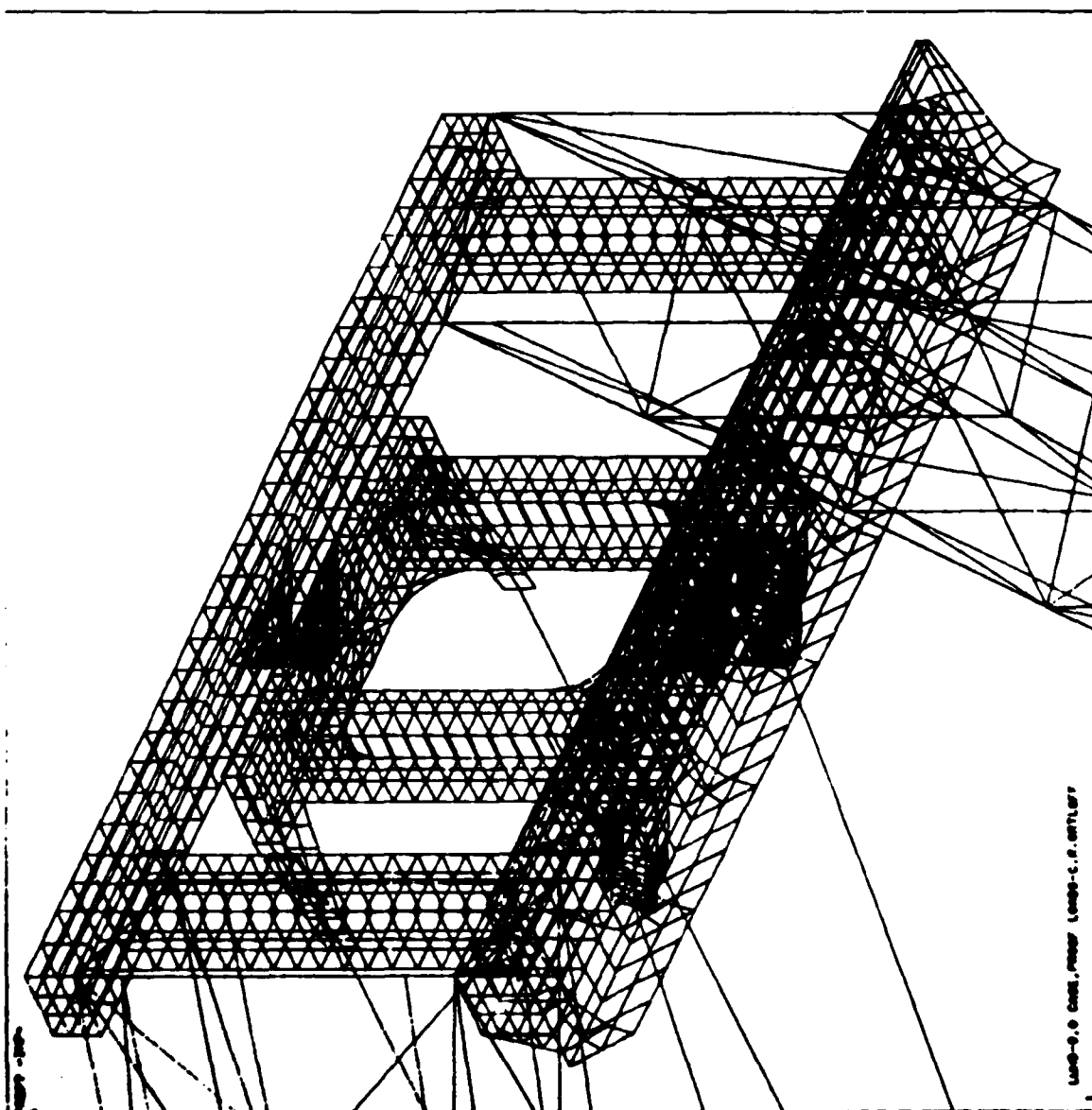


10000-1

10000-1 0.0000000 10000-1 0.0000000

00000 0.00
 0000 00 1000
 0000 00
 0000 000000

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|--------|
| 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 | 2042 | 2043 | 2044 | 2045 | 2046 | 2047 | 2048 | 2049 | 2050 | 2051 | 2052 | 2053 | 2054 | 2055 | 2056 | 2057 | 2058 | 2059 | 2060 | 2061 | 2062 | 2063 | 2064 | 2065 | 2066 | 2067 | 2068 | 2069 | 2070 | 2071 | 2072 | 2073 | 2074 | 2075 | 2076 | 2077 | 2078 | 2079 | 2080 | 2081 | 2082 | 2083 | 2084 | 2085 | 2086 | 2087 | 2088 | 2089 | 2090 | 2091 | 2092 | 2093 | 2094 | 2095 | 2096 | 2097 | 2098 | 2099 | 2100 | 2101 | 2102 | 2103 | 2104 | 2105 | 2106 | 2107 | 2108 | 2109 | 2110 | 2111 | 2112 | 2113 | 2114 | 2115 | 2116 | 2117 | 2118 | 2119 | 2120 | 2121 | 2122 | 2123 | 2124 | 2125 | 2126 | 2127 | 2128 | 2129 | 2130 | 2131 | 2132 | 2133 | 2134 | 2135 | 2136 | 2137 | 2138 | 2139 | 2140 | 2141 | 2142 | 2143 | 2144 | 2145 | 2146 | 2147 | 2148 | 2149 | 2150 | 2151 | 2152 | 2153 | 2154 | 2155 | 2156 | 2157 | 2158 | 2159 | 2160 | 2161 | 2162 | 2163 | 2164 | 2165 | 2166 | 2167 | 2168 | 2169 | 2170 | 2171 | 2172 | 2173 | 2174 | 2175 | 2176 | 2177 | 2178 | 2179 | 2180 | 2181 | 2182 | 2183 | 2184 | 2185 | 2186 | 2187 | 2188 | 2189 | 2190 | 2191 | 2192 | 2193 | 2194 | 2195 | 2196 | 2197 | 2198 | 2199 | 2200 | 2201 | 2202 | 2203 | 2204 | 2205 | 2206 | 2207 | 2208 | 2209 | 2210 | 2211 | 2212 | 2213 | 2214 | 2215 | 2216 | 2217 | 2218 | 2219 | 2220 | 2221 | 2222 | 2223 | 2224 | 2225 | 2226 | 2227 | 2228 | 2229 | 2230 | 2231 | 2232 | 2233 | 2234 | 2235 | 2236 | 2237 | 2238 | 2239 | 2240 | 2241 | 2242 | 2243 | 2244 | 2245 | 2246 | 2247 | 2248 | 2249 | 2250 | 2251 | 2252 | 2253 | 2254 | 2255 | 2256 | 2257 | 2258 | 2259 | 2260 | 2261 | 2262 | 2263 | 2264 | 2265 | 2266 | 2267 | 2268 | 2269 | 2270 | 2271 | 2272 | 2273 | 2274 | 2275 | 2276 | 2277 | 2278 | 2279 | 2280 | 2281 | 2282 | 2283 | 2284 | 2285 | 2286 | 2287 | 2288 | 2289 | 2290 | 2291 | 2292 | 2293 | 2294 | 2295 | 2296 | 2297 | 2298 | 2299 | 2300 | 2301 | 2302 | 2303 | 2304 | 2305 | 2306 | 2307 | 2308 | 2309 | 2310 | 2311 | 2312 | 2313 | 2314 | 2315 | 2316 | 2317 | 2318 | 2319 | 2320 | 2321 | 2322 | 2323 | 2324 | 2325 | 2326 | 2327 | 2328 | 2329 | 2330 | 2331 | 2332 | 2333 | 2334 | 2335 | 2336 | 2337 | 2338 | 2339 | 2340 | 2341 | 2342 | 2343 | 2344 | 2345 | 2346 | 2347 | 2348 | 2349 | 2350 | 2351 | 2352 | 2353 | 2354 | 2355 | 2356 | 2357 | 2358 | 2359 | 2360 | 2361 | 2362 | 2363 | 2364 | 2365 | 2366 | 2367 | 2368 | 2369 | 2370 | 2371 | 2372 | 2373 | 2374 | 2375 | 2376 | 2377 | 2378 | 2379 | 2380 | 2381 | 2382 | 2383 | 2384 | 2385 | 2386 | 2387 | 2388 | 2389 | 2390 | 2391 | 2392 | 2393 | 2394 | 2395 | 2396 | 2397 | 2398 | 2399 | 2400 | 2401 | 2402 | 2403 | 2404 | 2405 | 2406 | 2407 | 2408</ |
|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|--------|



D3/130

CEL MEMO: DECEMBER 19, 1986

FMC Central Engineering Laboratories
Santa Clara

Interoffice

To R. Rathe

From C. R. Ortloff

Subject **PROGRESS REPORT ON ASSIGNED TASKS**
LWHD PROJECT (12/5 TO 12/18)

Date Dec. 19, 1986

cc E. Thuse
R. Kazares
P. Carroll
J. Ries
B. Anderson
E. Alexander
B. Zierwick
L. Libhardt

TOTAL SYSTEM MODEL

A report on the dynamic motion and concomitant dynamic stress states of the total LWHD system (cradle, platform, gimbal, trails) was completed and forwarded to NOD (CRO to L. Libhardt, 12/16). This dynamic load case represented the 0° elevation, 0° gimbal rotation case (79 figures forwarded). Three further FE models (of 3,400 elements each) have been constructed for the 0° - 72°, 22.5° - 0°, 22.5° - 72° cases and are currently residing on the VAX queue for execution. Each case represents about 34 CPU hours of run and postprocessing time and requires about 400,000 blocks of file space to store results. Since the current available disk space is about 450,000 blocks, each run must be postprocessed and stored on tape before the next run can be effectively started. Turn-around time per run under current operating conditions is about 3-4 days.

During Christmas holidays when batch usage is low, I hope to run the remaining programs continuously to try to get most of these load cases done and postprocessed. Additional load cases remaining (LAPES, etc.) plus ones on the queue most likely total up to several hundred CPU hours remaining to fully analyze the LWHD under dynamic load conditions.

CRADLE

* The hardcopy output for the latest static cradle run was forwarded (12-16) in addition to element and node maps. Since recent work on the dynamic amplification factor indicates a value between 1 to 1.5, failure of the current design is likely (memo, CRO to R. Rathe, 12/8/86) in a number of different modes under proof loads. A possible suggestion you may wish to consider for a cradle design "fix" was included with this memo. Use of additional Gr/Ep layers in selected cradle regions can reinforce the current design to make it meet design allowables. Since the cradle design is going through another design iteration (memo, J. Reis to C. R. Ortloff, 12/5/86), it is unclear whether the work performed to date will be used. A decision on a design change from a filament-wound 14 layer foam-core sandwich to woven roving lay-up structure has not yet been transmitted to me as of 12/19. Regardless of the design choice, I can easily

R. Rathe
Progress Report on Assigned Tasks
LWHD Project (12/5 to 12/18)


Dec. 19, 1986
Page 2

modify the existing cradle program to accommodate new design changes and material properties. The CPU time per run is about 10-12 CPU hours so turnaround time is not excessive to compare "new" to "old" designs.

From this point forward, with your concurrence, any cradle runs will include thermal expansion induced stresses at "hot" conditions. An estimation of moisture absorption stresses is important as both the laminate stiffness and strength properties change primarily through changes in epoxy properties. I will perform a FPF analysis for hygrothermal effects for the laminate design you ultimately choose for $C = 1\%$ and $T = 160^{\circ}\text{F}$, based on one of the quadratic lamina failure criteria. Since this type of analysis is strongly dependent upon epoxy and fiber materials properties and ply stacking sequence, I will need an update on your latest design to perform this work. This effect may cause a significant change in either direction in laminate strength under hot, wet conditions depending on the final choice of the stacking sequence and load type. You may want to consider a test program to measure effects (upon your laminate design) to more precisely gage this effect (as this is the usual procedure for assessment of the hygrothermal stress effect).

do we
want
this?
Z

Please keep me informed of recent design changes so that I can modify my (current) FE models and provide you with current results as quickly as possible.


C. R. Ortloff

FMC Central Engineering Laboratories
Santa Clara

Interoffice

To L. Libhardt*

Date Dec. 17, 1986

From C. R. Ortloff

cc E. Thuse
A. Amberg
R. Kazares
R. Rathe
E. Alexander
J. Ries
B. Anderson
T. Rudolf
B. Zierwick

Subject **STRESS LEVELS IN THE PLATFORM AND GIMBAL
UNDER DYNAMIC (PROOF) FIRING LOADS -
0° ELEVATION, 0° GIMBAL ROTATION CASE**

*one copy of original
figures only

79 Figures - ~~192~~ 272

An ANSYS finite element model of the platform, gimbal, spades and trails has been made. A representative beam-element model of the cradle-cable system has been added to this model with the correct mass and moment of inertia values. The model is then impulsively loaded with firing torque and recoil impulse loads and the dynamic motion and stress states (at given selected times) determined. The boundary conditions are:

- o no constraints on the trail ends
- o the spade lower edge is fixed
- o no vertical deflection of the horizontal plane of the lower plate of the platform, i.e. $U_Y = 0$ on the bottom horizontal plane adjacent to the spade. This condition corresponds to emplacement in "hard" soil.

what
w2.?
16 too?

} correct?

The input loads correspond to the proof load maximums and time durations previously specified. The dynamic deflection under impulse loads is shown at selected Master Degree of Freedom (MDOF) nodes in the structure and is shown in figures 197-217. The locations of these MDOF nodes is shown in figures 193-196. The trailing arm locations (figure 195) are seen to have a deflection time history (figure 208) indicating several inches of bounce. The trail model used consists of a foam-core sandwich upper plate (9 Gr/Ep lamina [0/45/-45/90/0/90/-45/45/0] over a 2 inch Rohacell core) with the metal matrix truss structure (Al/SiC) and Ti bulkhead reinforcing plates (after the Concept 3 Trail Drawing, 10-29-86 and 11-12-86, D. Langerud). Although the trail design is not yet fixed (as of 12-16-86), the free-end boundary condition reduces its importance as a load carrying member (over previous fixed-end trail configurations). The trails may then be designed to static load conditions with an appropriate safety factor (2).

what?

+ transparent
load?

As usual for Linear Transient Dynamic Analysis, peaks in deflection-time history (on the gimbal-platform) provide corresponding stress maximums in the structure. Several times are selected in the time interval from 0 to 1 second at which stress "snapshots" can be obtained for the structure by ANSYS stress-pass methods. Times selected are 0.013, 0.28 and 0.428 seconds and correspond to displacement peaks in several of the MDOF's on the main structure. The initial time is at the end of the firing torque input; the second time is slightly after the recoil impulse input. A damping value of (ANSYS) DAMP = 0.2E-2 is included to reduce later-time spurious dynamic peaks in the displacement-time histories. Once the final configuration/materials of the composite parts of the structure are decided and a damping value justified then a rerun can be made to include values of ALPHAD, BETAD for final production runs. As damping dissipates energy, present stress/deflection values are on the conservatively high side with respect to this effect.

* Figures 225-263 show Von Mises equivalent stress contours on the Ti gimbal/platform outer surface. Over most of the structure, stresses are well within the yield stress for Ti (60-80 ksi) under proof loads. Stress values in the connection tabs (figures 242, 247 for example) are near the yield stress locally. Also, gimbal upper and lower openings in the upper and lower box beams show high stress values (figures 248, 249, 250, 251, 252, 253, 259, 261, 262, 263). Since these bearing areas are undoubtedly to be reinforced locally (once bearing details are decided upon) these locally high stress values can be easily lowered by (locally) mounted reinforcing plates. * when? OK

Details of the bearing-tab-gimbal model are shown in figures 269-272. Beam elements (STIF 4) with the appropriate mass and inertia properties appropriate to the latest design are the vertical shafts shown. Rigid beam elements connect the shaft(s) to the tabs/gimbal openings as shown. Since the STIF 4 beam element has no torsional stiffness, a supplementary beam ties the gimbal to the platform to prevent relative motion between gimbal and platform under any torque loads. Since loads on the structure are on-axis along the centerline, no significant shaft rotation is expected and the load entering the shaft(s) is primarily directed to cause bending. To access the shaft bending stresses (in addition to other tension/compression effects present), recourse to figures 270 (bottom shaft) and 271 (upper shaft) is made. Reference to the ANSYS User's Manual, V. 1, p. 4.4.4, and figures 266-268 (at t = 0.28 sec after the recoil loads have been input into the system) indicate a bottom shaft outer fiber stress maximum of 6035 psi at node 3461. For the top shaft, the maximum stress is on the order to 22,000 psi. slight that initial what?

L. Libhardt
Stress Levels in the Platform and Gimbal
Under Dynamic (Proof) Firing Loads -
0° Elevation, 0° Gimbal Rotation Case

Dec. 17, 1986
Page 3

In all the above calculations, the mass and rotary inertia of the cradle are simulated with its CG approximately duplicated from the cradle model. Distributed masses are also included throughout by means of specifying the material density.

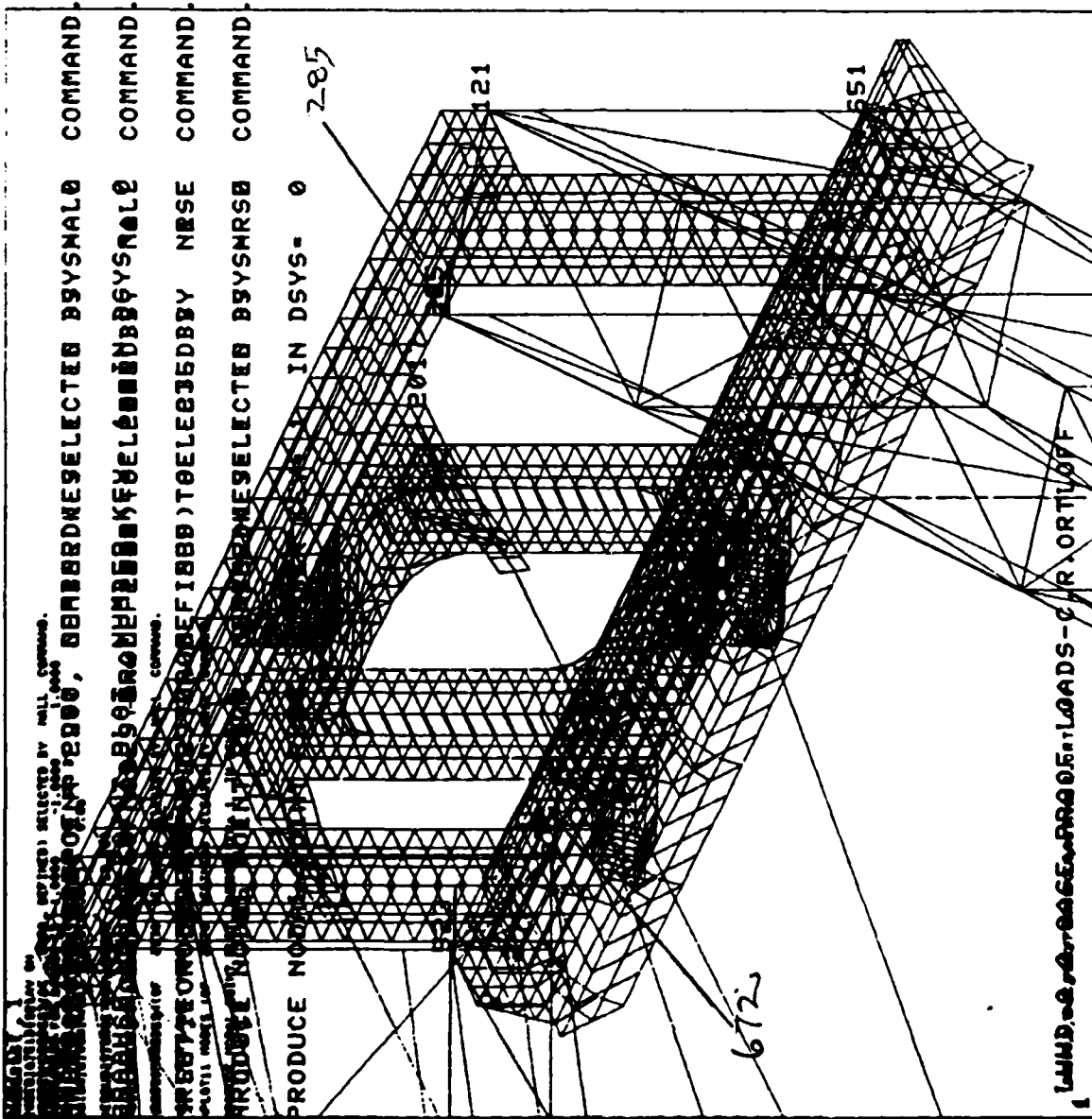
Conclusions

- o Except for some local zones around the bearings of the upper portion of the gimbal and the associated platform tab/upper shaft region, stresses under proof loads in both platform and gimbal appear to be much less than the 60-80 ksi Ti proportional limit stress (figures 225-263).
- o These zones may be easily reinforced by additional weld-on or bolt-on plates in the bearing areas on the box beam sections.
- o The upper shaft stress is about 20 ksi.
- o The system appears stable under dynamic loads in the 0° elevation, 0° gimbal rotation mode for the given set of boundary conditions, although it appears that the trail ends "lift off" the ground upon firing. It would probably be better to retain end stakes/claws on the trails to limit system "bounce" to a minimum.
- o In total, the stress analysis results look positive for the current design under proof firing loads with only minor changes required to reduce some local stresses to acceptable values.
- o CPU time for the current results set in 34 CPU hours. Inclusion of ALPHAD, BETAD damping will increase run time to over 42 cpu hours. With additional time related to post-processing, it is imperative that subsequent design changes be made in response to stress deficiencies as a matter of priority so that at least one "workable" design exists before further revisions are made.

Since original figures have been forwarded with all memos sent to date, it is imperative that they be stored in a cool, dark place to preserve them. When a final stress report is to be written, some of these figures will need to be sent back to me for inclusion into the final report.


C. R. Ortloff

**



ANSYS 4.20
DEC 5 1986
10:26:10
PREP7 ELEMENTS

ZOOM
XU=-1
YU=-1
ZU=1
DIST=58.1
XF=100
YF=79.7
ZF=52.5
XRT0=1.17

MDOF
NODES

PREP7 NODES

ZOOM
XU=-1
YU=-1
ZU=1
DIST=58.1
XF=100
YF=79.7
ZF=52.5
XRT0=1.17

PREP7 NODES

ZOOM
XU=-1
YU=-1
ZU=1
DIST=58.1
XF=100
YF=79.7
ZF=52.5
XRT0=1.17

PREP7 NODES

ZOOM
XU=-1
YU=-1
ZU=1
DIST=58.1
XF=100
YF=79.7
ZF=52.5
XRT0=1.17

PREP7 NODES

ZOOM
XU=-1
YU=-1
ZU=1

PRODUCE NODES
IN DSYS = 0
285

LOADS = 0.5 * R.ORTLOFF

```

ANSYS 4.80
DIC 5 1980
102610
PREP7 ELEMENTS

ZOOM
XU=-1
YU=-1
ZU=-1
8 DIST=58.1
8 HF=100
8 VF=79.7
8 ZF=52.5
8 XRT0=1.17

PREP7 MODCS

ZOOM
XU=-1
YU=-1
ZU=-1
8 DIST=58.1
8 HF=100
8 VF=79.7
8 ZF=52.5
8 XRT0=1.17

PREP7 MOD

ZOOM
XU=-1
YU=-1
ZU=-1
8 DIST=58.1
8 HF=100
8 VF=79.7
8 ZF=52.5
8 XRT0=1.17

PREP7 MOD

ZOOM
XU=-1
YU=-1
ZU=-1
8 DIST=58.1
8 HF=100
8 VF=79.7
8 ZF=52.5
8 XRT0=1.17

PREP7 MOD

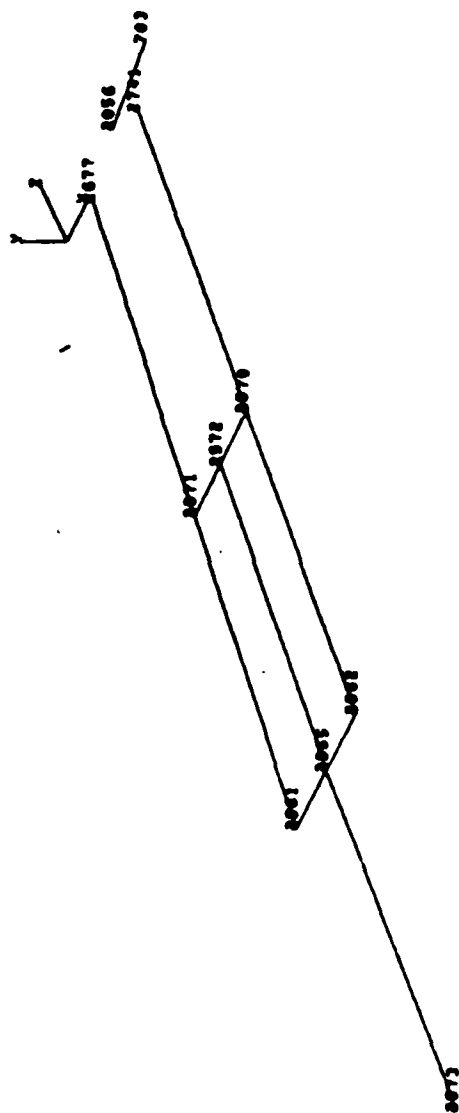
ZOOM
XU=-1
YU=-1
ZU=-1
8 DIST=58.1
8 HF=100
8 VF=79.7
8 ZF=52.5
8 XRT0=1.17

PREP7 MOD

```


46-1-01

LUNY-0,0 CASE, PROOF LOADS-C.R. ONYLOFF



10

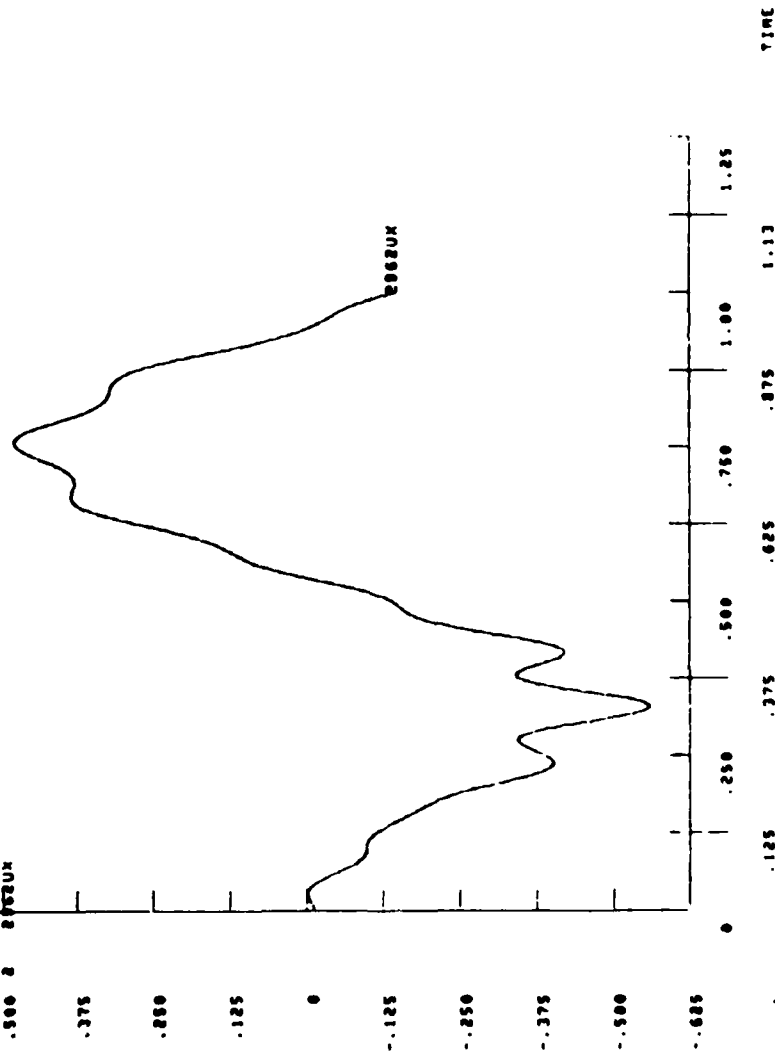
0157.2.0000.UX
 POSTAGE-IMP.
 VARIABLE 2 IS 0002 UX PHASE REV. 0
 POSTAGE-IMP.
 PLUMB,2

STORAGE COMPLETE FOR 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES

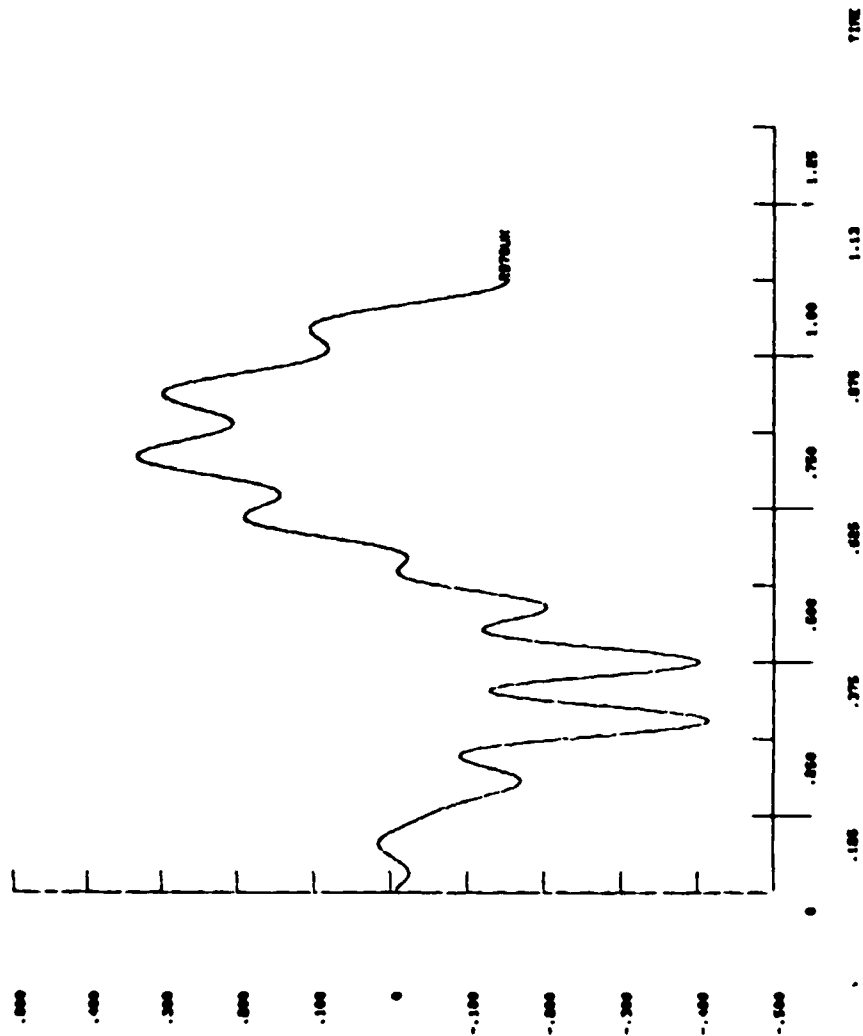
| VARIABLE IDENTIFIERS | NAME | MINIMUM | AT TIME | MAXIMUM | AT TIME |
|----------------------|--------|---------|---------|---------|---------|
| 2 0157.2.0000.UX | 2062UX | -0.5587 | 0.3200 | 0.4810 | 0.7570 |

PLOT DEFINITION
 CURVE VARIABLE
 1 .500 2 2062UX



1 LUMB-0.0 CASE, PROOF LOADS-C.0.007LOFF

RECONSTRUCTED FOR 1001 DATA POINTS
 SUMMARY OF VARIOUSLY STOPPED AND STOPPED VALUES
 AND TWO STOPPED AND STOPPED VALUES AT THE
 A STOP STOP AT STOP -0.4100 0.0000 0.0000 0.0000
 STOP STOP STOP STOP STOP STOP STOP STOP STOP STOP
 STOP STOP STOP STOP STOP STOP STOP STOP STOP STOP
 STOP STOP STOP STOP STOP STOP STOP STOP STOP STOP

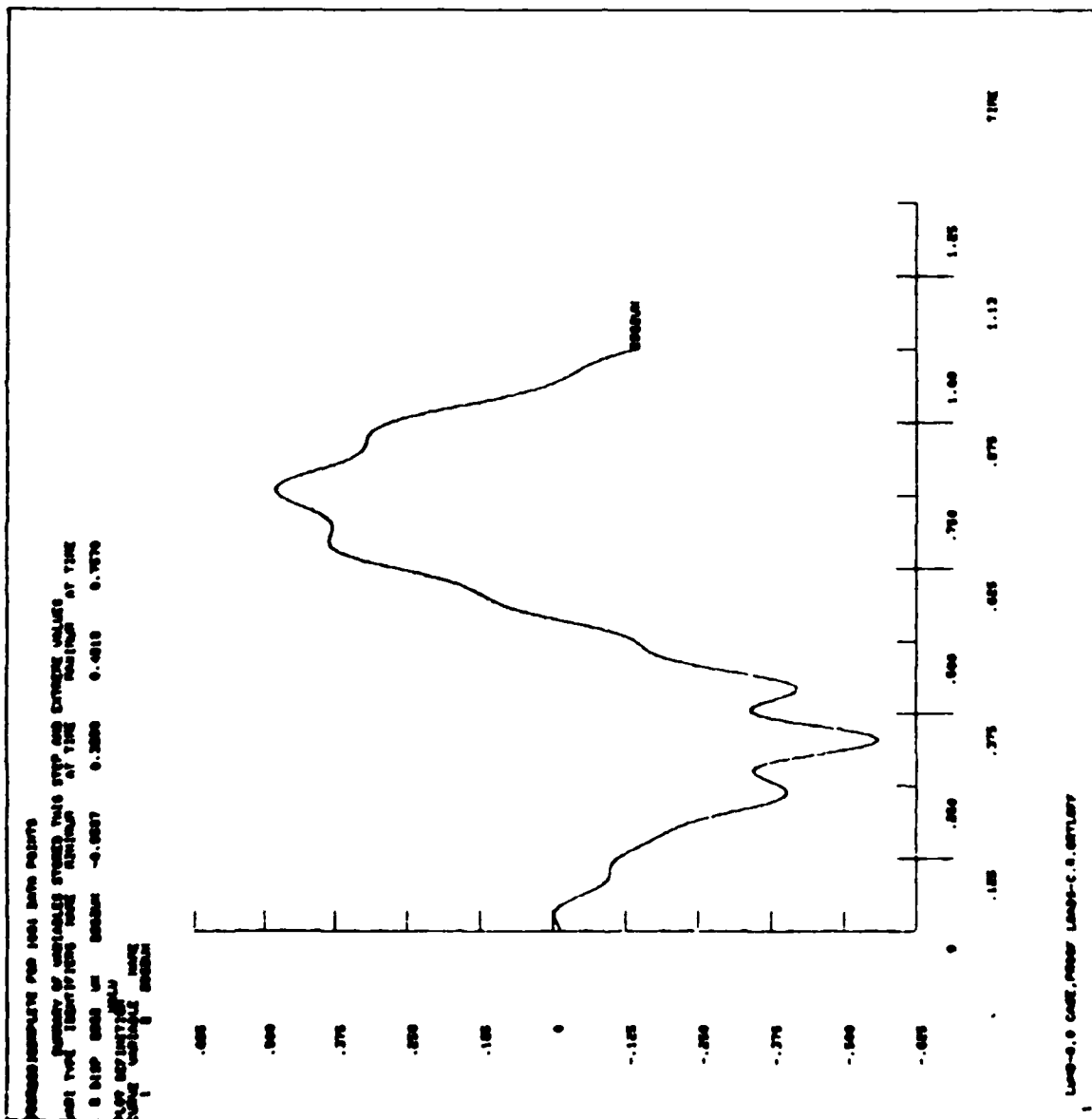


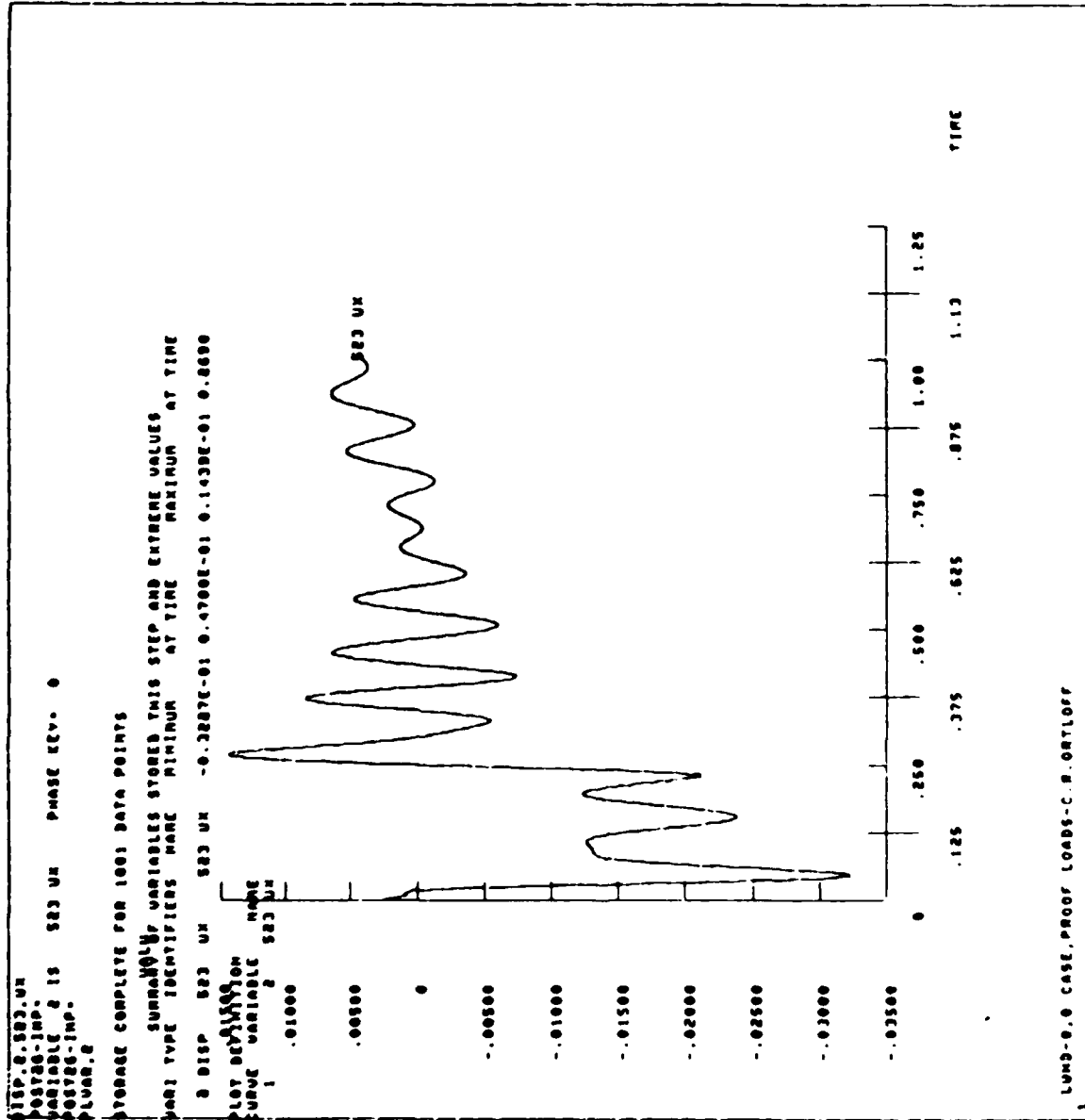
1. LINE-0.0 CASE, PAPER LENGTH-0.0, STOPPED

PAPER
 20-1
 0187-1.20

199

POSTER
20-1
0107-1.20



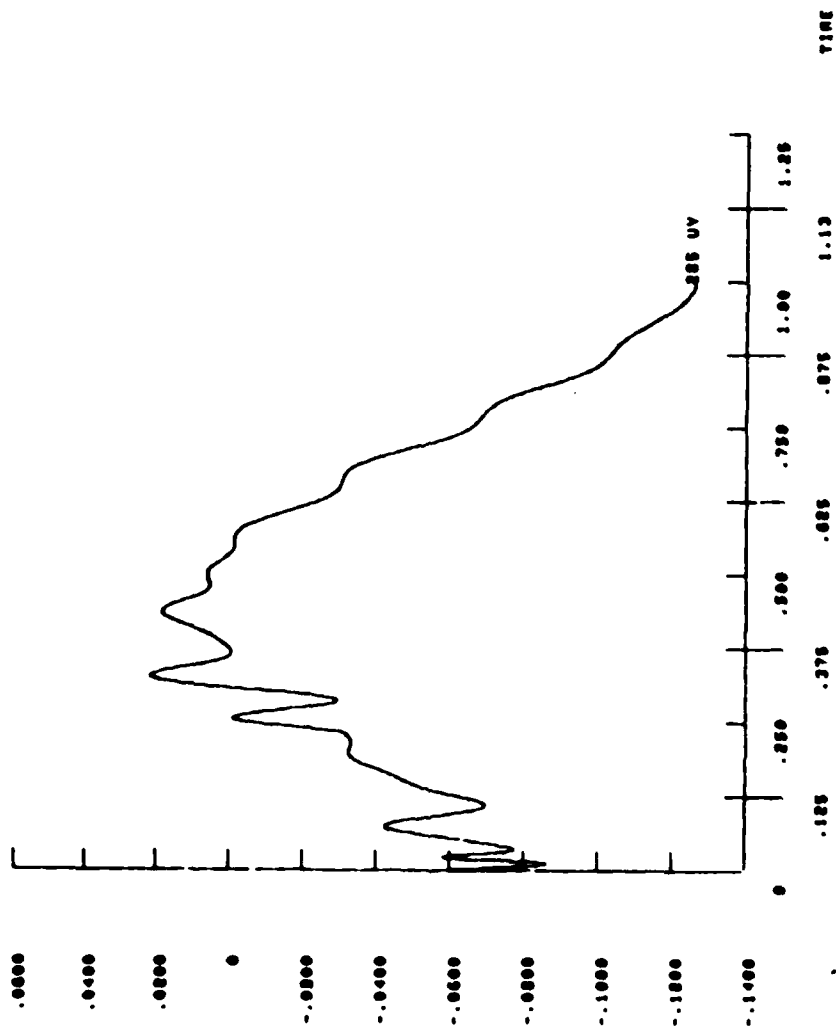


*****COMPLETE FOR 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES
 1001 TYPE IDENTIFIERS NAME MINIMUM AT TIME MAXIMUM AT TIME

2 010P 288.0 UV 288 UV -0.1000 1.000 0.0100E-01 0.3870

PLOT DEFINITION
 CURVE VARIABLE NAME
 1 288 UV



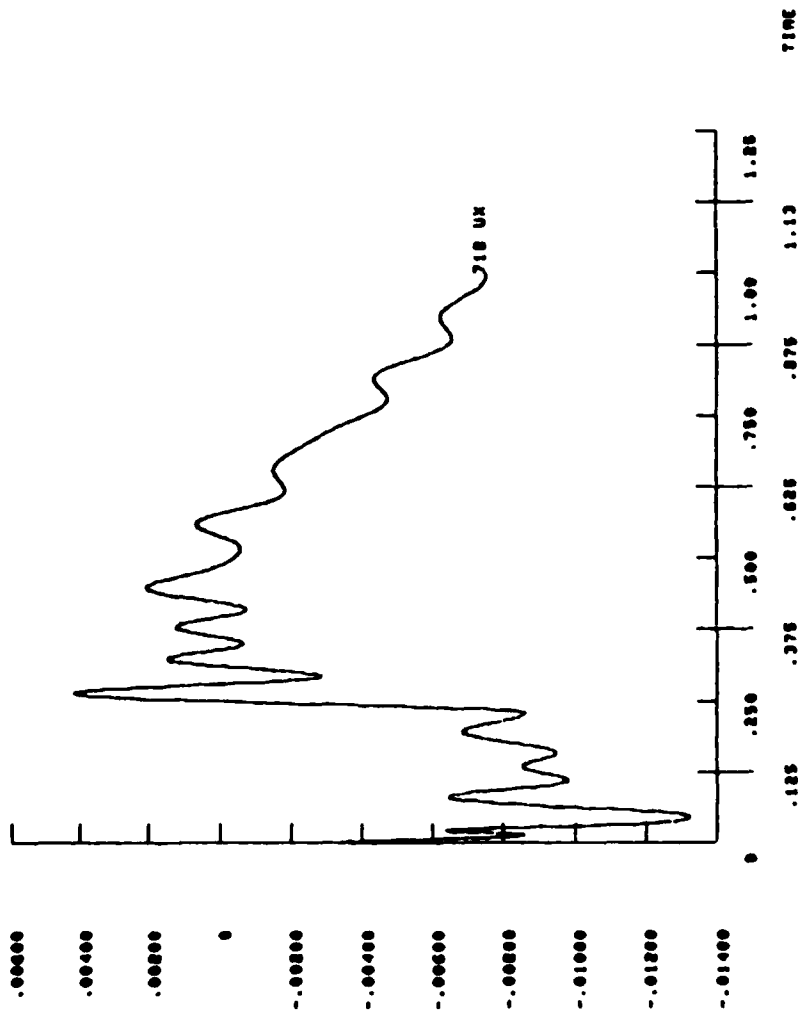
1 LWB-0.0 CASE, PROOF LOADS-C.R.001077

*****COMPLETE FOR 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES
 VARIABLE IDENTIFIER NAME MINIMUM AT TIME MAXIMUM AT TIME

8 DISP 710 UX 710 UX -0.1324E-01 0.4000E-01 0.4181E-02 0.0000

PL07 DEFINITION
 1 NAME
 2 CURVE VARIABLE 710 UX



1 LUND-0.0 CASE, PROOF LOADS-C.B. ONTLOFF

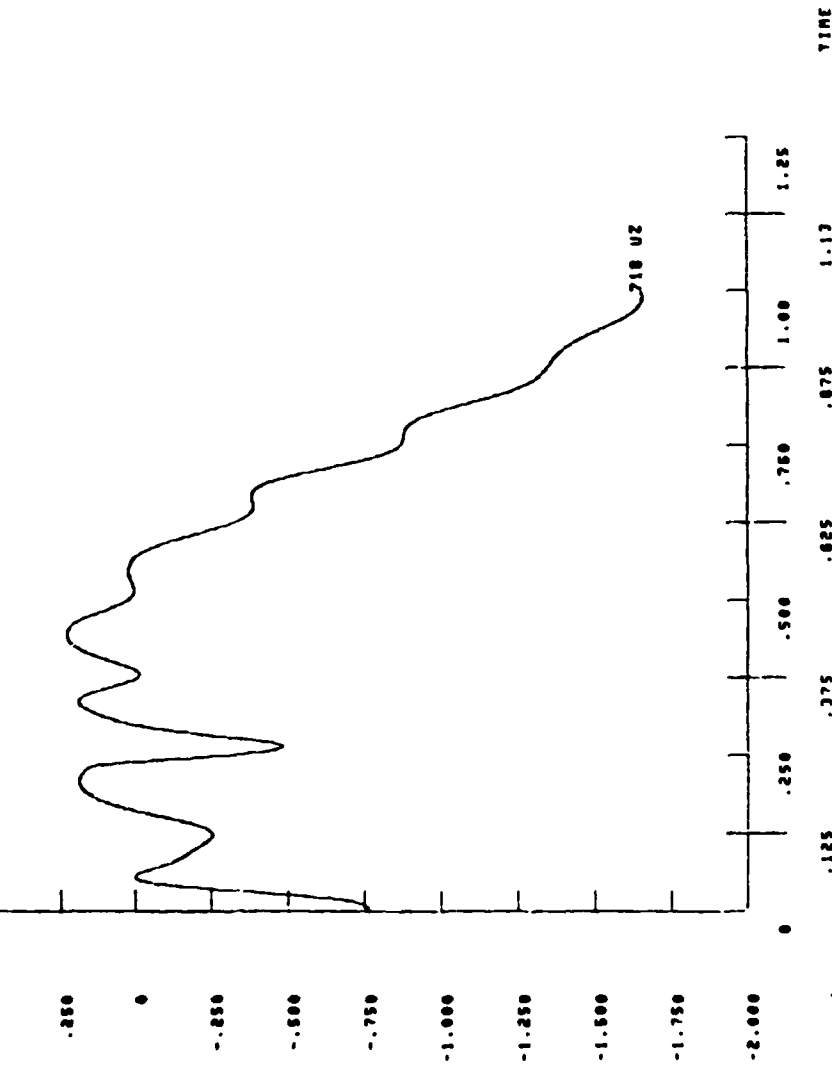
POORGEIDCOMPLETE FOR 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES

| VARI TYPE | IDENTIFIERS | NAME | MINIMUM | AT TIME | MAXIMUM | AT TIME |
|-----------|-------------|--------|---------|---------|---------|---------|
| 2 DISP | W91W UZ | 718 UZ | -1.635 | 0.9910 | 0.2319 | 0.4470 |

PLOT DEFINITION

| CURVE | VARIABLE | NAME |
|-------|----------|--------|
| 1 | 718 UZ | 718 UZ |

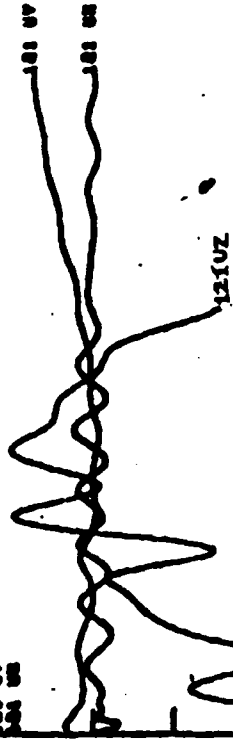


1 LUMB-0.0 CASE, PROOF LOADS-C.R.ORTLOFF

SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES

| NAME | MINIMUM | AT TIME | MAXIMUM | AT TIME |
|--------|-------------|---------|---------|---------|
| 101 UX | -9.174 | 1.000 | 1.000 | 0.4000 |
| 101 UY | -0.0000E-01 | 0.000 | 0.000 | 0.0010 |
| 101 UZ | -0.0000E-01 | 0.000 | 0.000 | 0.0000 |

NAME
101 UX
101 UY
101 UZ



121 UZ

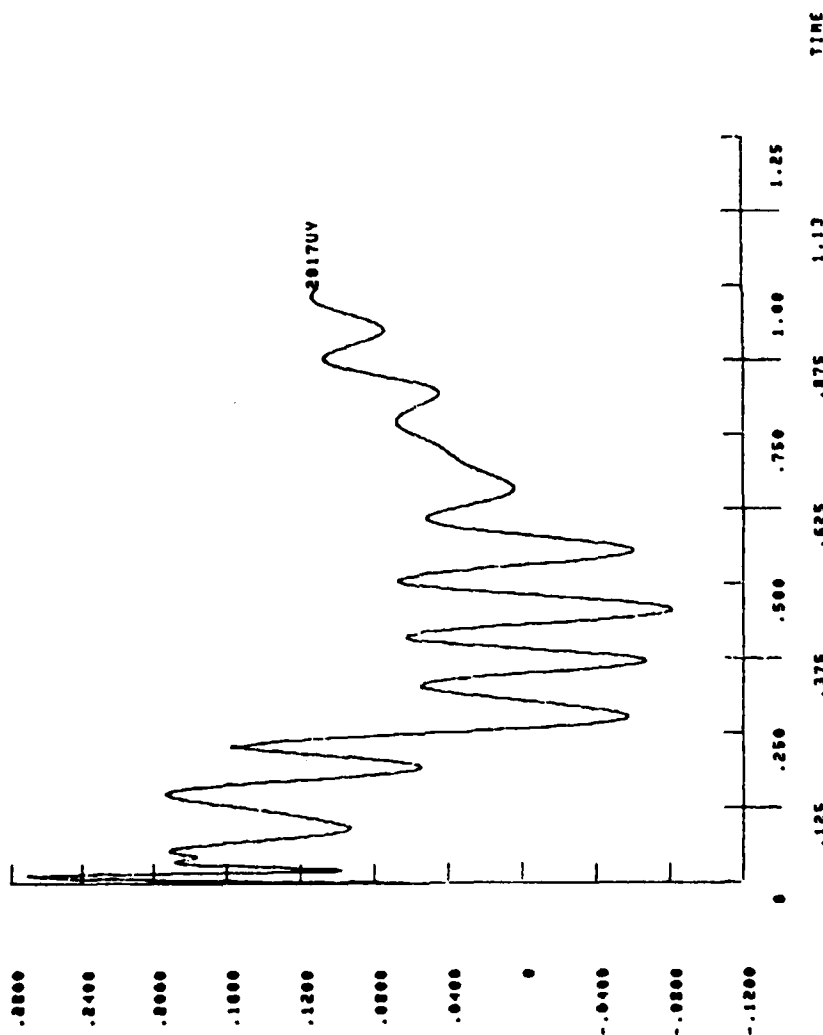
121 UX
UY
UZ

INCOMPLETE FOR 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES
 VARIABLE IDENTIFIERS NAME MINIMUM AT TIME MAXIMUM AT TIME

2 DISP 2017UV 2017UV -0.8165E-01 0.4570 0.2712 0.1300E-01

PLOT DEFINITION
 CURVE VARIABLE NAME
 1 2017UV
 2 2017UV



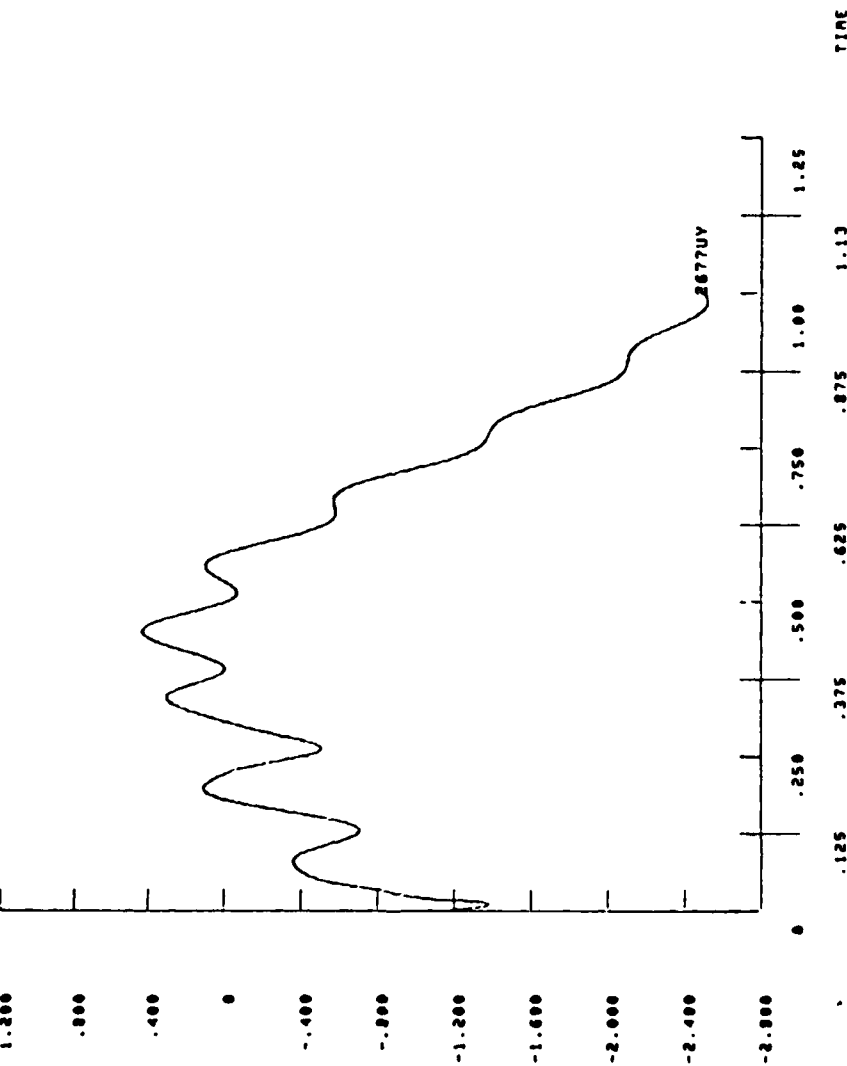
1 LUMP-0.0 CASE, PROOF LOADS-C.R. ORYLOFF

SOURCE: COMPLETE FOR 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES
 NAME TYPE IDENTIFIERS NAME MINIMUM AT TIME MAXIMUM AT TIME

R DISP 8034 UV 2677UV -2.520 0.0870 0.4293 0.4500

PLOT DEFINITION
 CURVE VARIABLE NAME
 1 1.200 2677UV
 2 2677UV

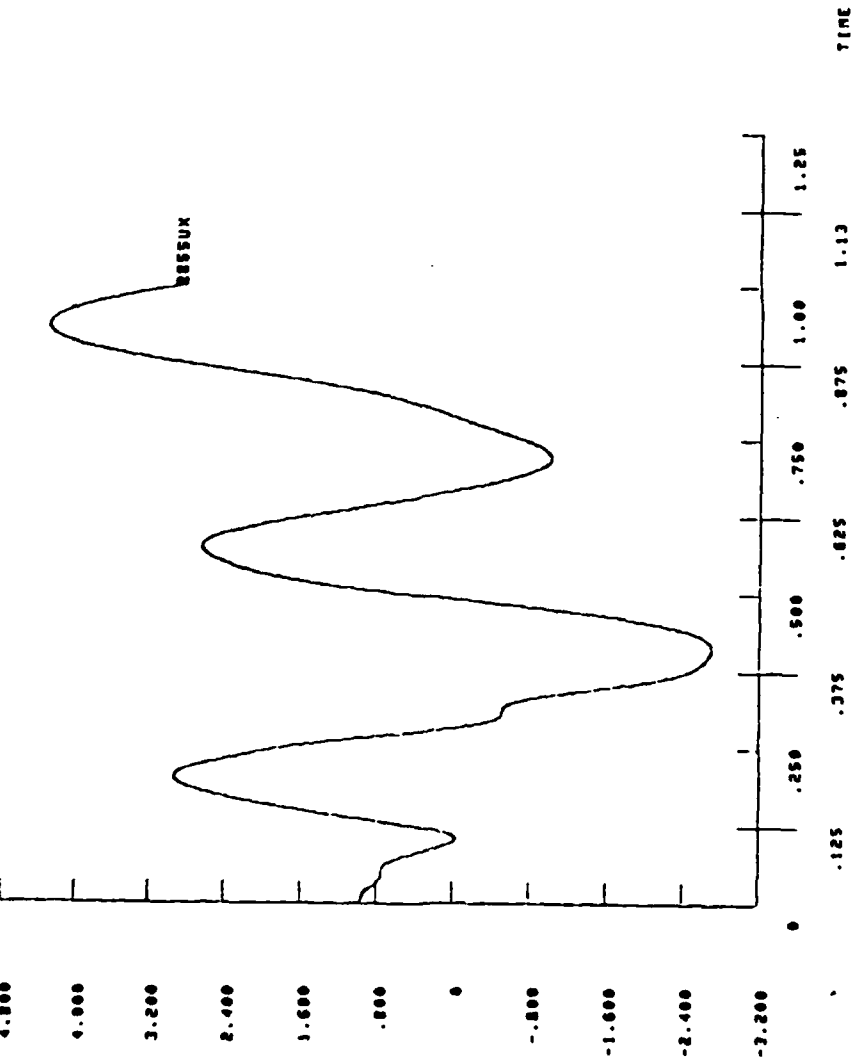


LUND-0.0 CASE, PROOF LOADS-C.R.ORTLOFF

*****COMPLETE FOR 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES
 VAR1 TYPE IDENTIFIERS NAME MINIMUM AT TIME MAXIMUM AT TIME
 1 DISK 2084 UX 2085UX -2.600 0.4130 4.313 0.9330

PLOT DEFINITION
 CURVE VARIABLE NAME
 1 4.800 2085UX
 2

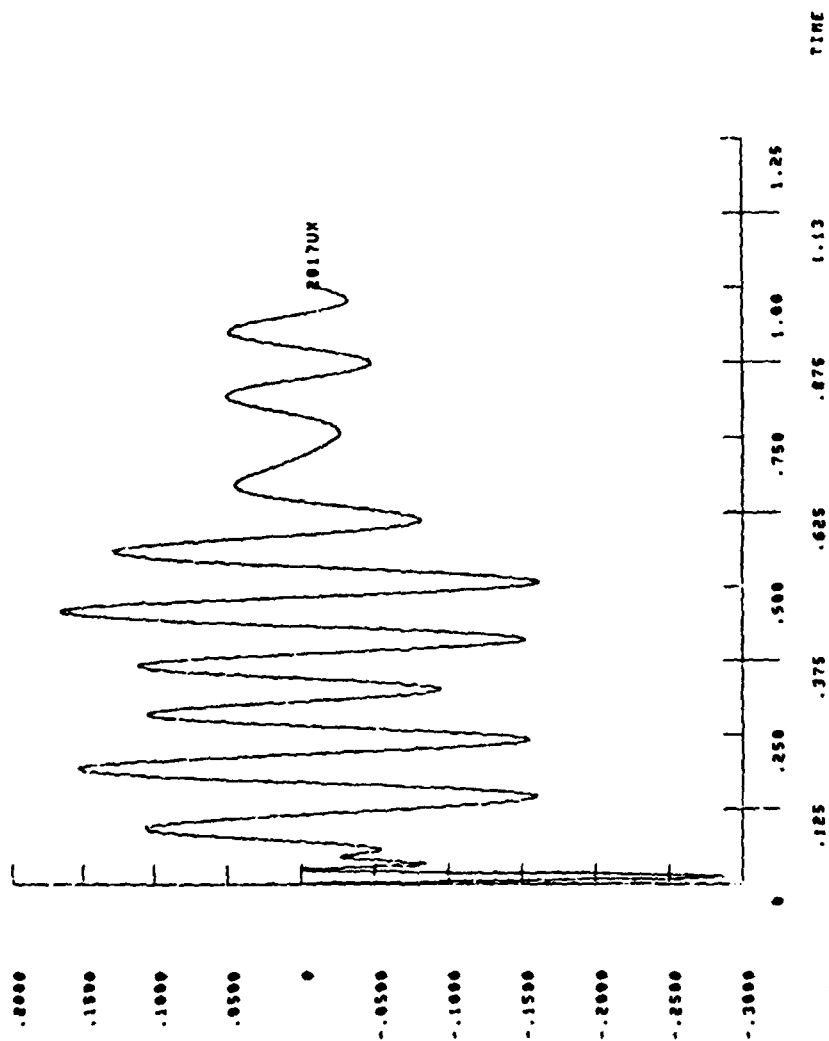


1 LUMB-0.0 CASE, PROOF LOADS-C.P. ORTLOFF

ON TRAILS

| SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES | | | | |
|--|------|-------------|------|--|
| WARD | TYPE | IDENTIFIERS | MADE | MINIMUM AT TIME MAXIMUM AT TIME |
| 8 | DISP | 201711 | UX | 201711X -0.2863 0.1308E-01 0.1660 0.4520 |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 | 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 | 70 | 71 | 72 | 73 | 74 | 75 | 76 | 77 | 78 | 79 | 80 | 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 | 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 | 98 | 99 | 100 |
|-----------------|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|-----|
| PLOT DEFINITION | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| CURVE VARIABLE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| NAME | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2017UX | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

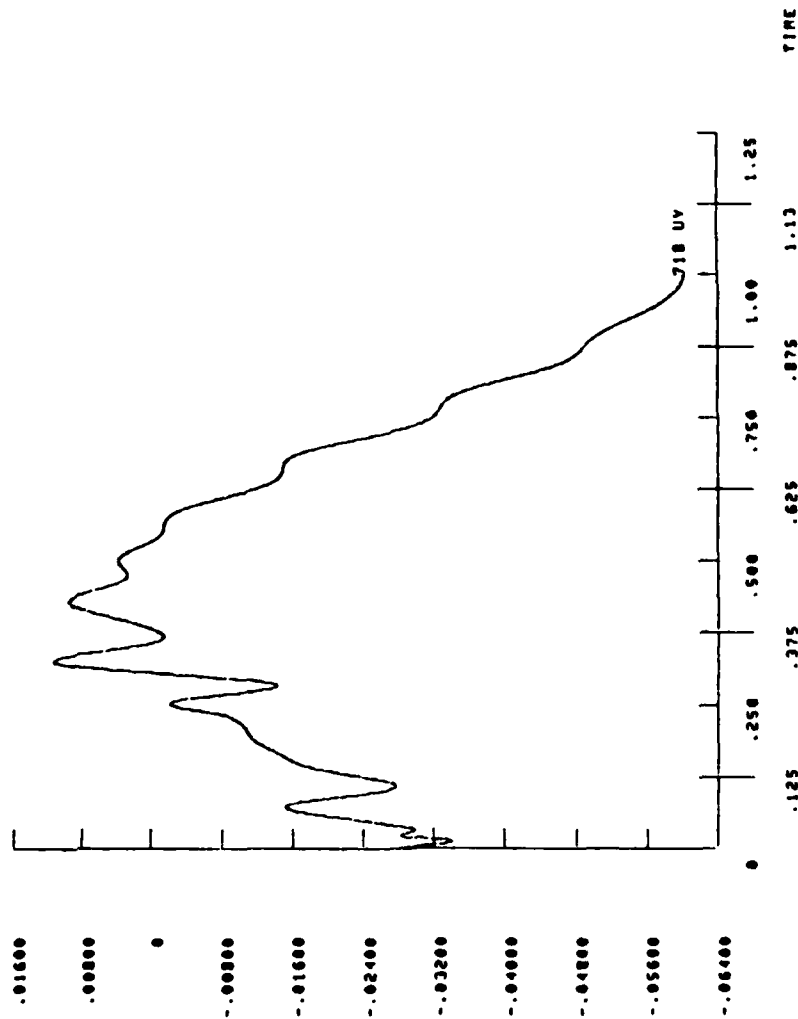


LUND-0.0 CASE, PROOF LOADS-C.A.ORTLOFF

POORERCOMPLETE FOR 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES
 NAME TYPE IDENTIFIERS NAME MINIMUM AT TIME MAXIMUM AT TIME
 2 DISP 718 UV 718 UV -0.6080E-01 1.000 0.1138E-01 0.3260

PLOT DEFINITION
 CURVE VARIABLE NAME
 1 2 718 UV

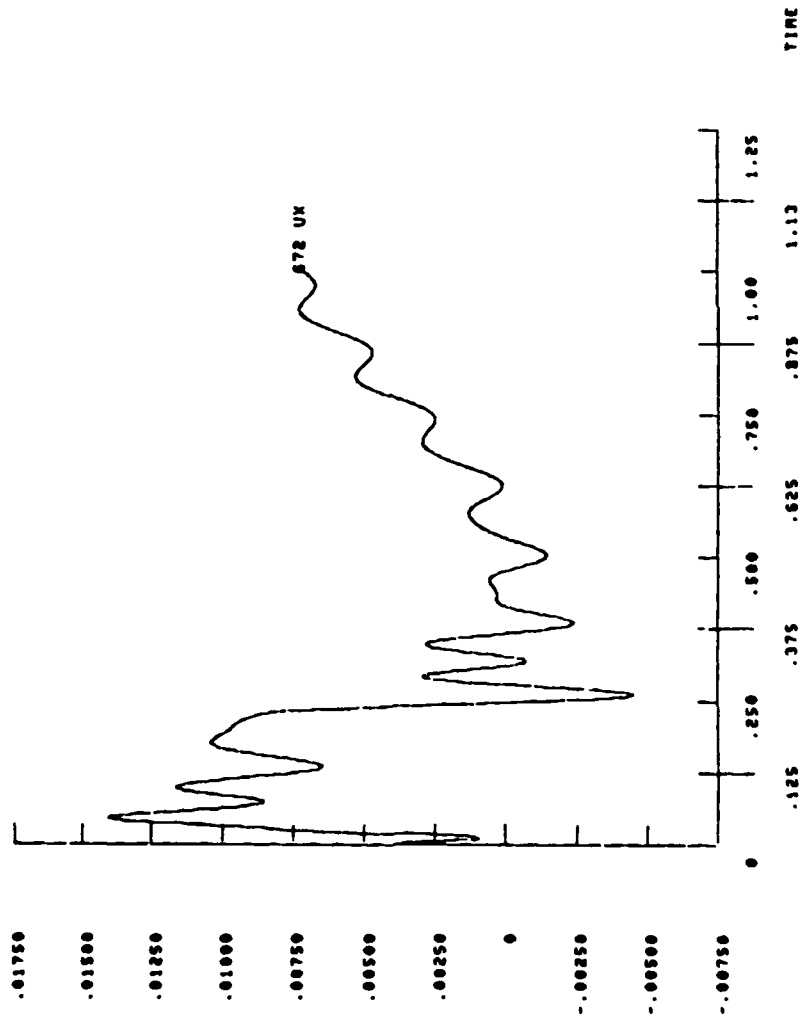


1 LUMB-0.0 CASE, PROOF LOADS-C.R.ORTLOFF

PROB001 COMPLETE FOR 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES
 NAME TYPE IDENTIFIERS NAME MINIMUM AT TIME MAXIMUM AT TIME
 2 B1SP 672 UX 672 UX -0.4518E-02 0.2610 0.1403E-01 0.4500E-01

PLOT DEFINITION
 CURVE VARIABLE NAME
 1 672 UX



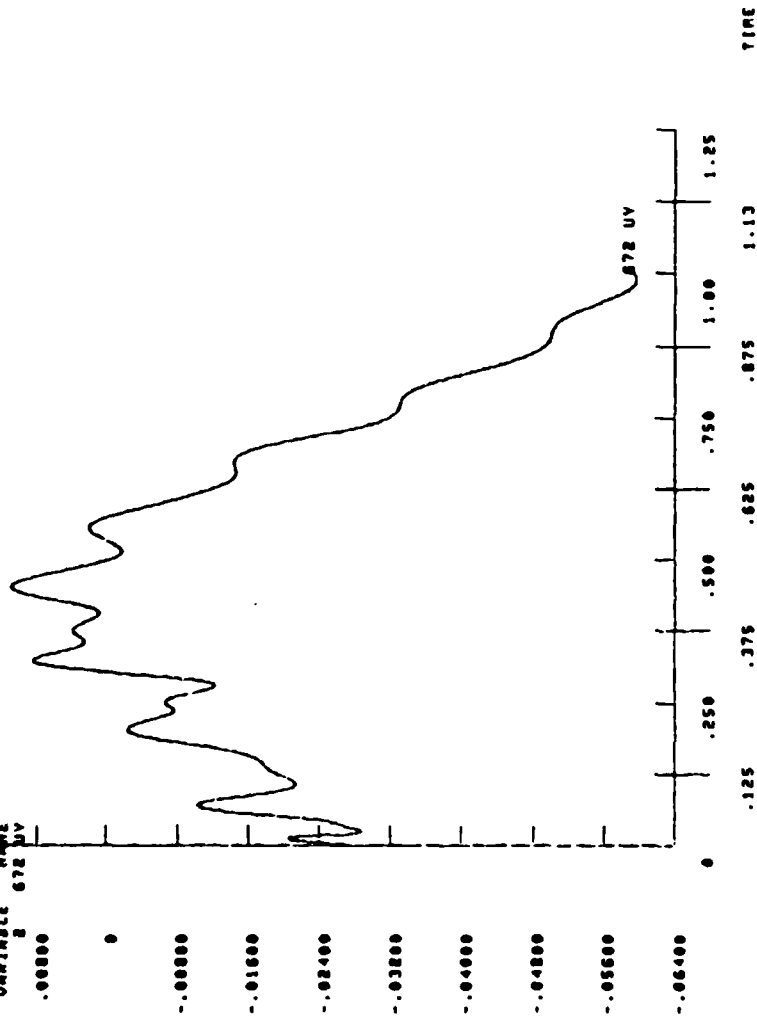
1 LUMB-0.8 CASE, PROOF LOADS-C.R.ORTLOFF

STEP 8.072 UV
POSTAGE-IMP.
VARIABLE 2 IS 672 UV PHASE REV. 0
POSTAGE-IMP.
PLVAR.2

STORAGE COMPLETE FOR 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES
VARIABLE IDENTIFIERS NAME MINIMUM AT TIME MAXIMUM AT TIME
2 81SP 672 UV 672 UV -0.0981E-01 0.0000 0.1101E-01 0.4510

PLOT DEFINITION
CURVE VARIABLE NAME
1 672 UV
2 672 UV



1 LUMB-0.8 CASE, PROOF LOADS-C.R. ORTLOFF

INCOMPLETE FOR 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES

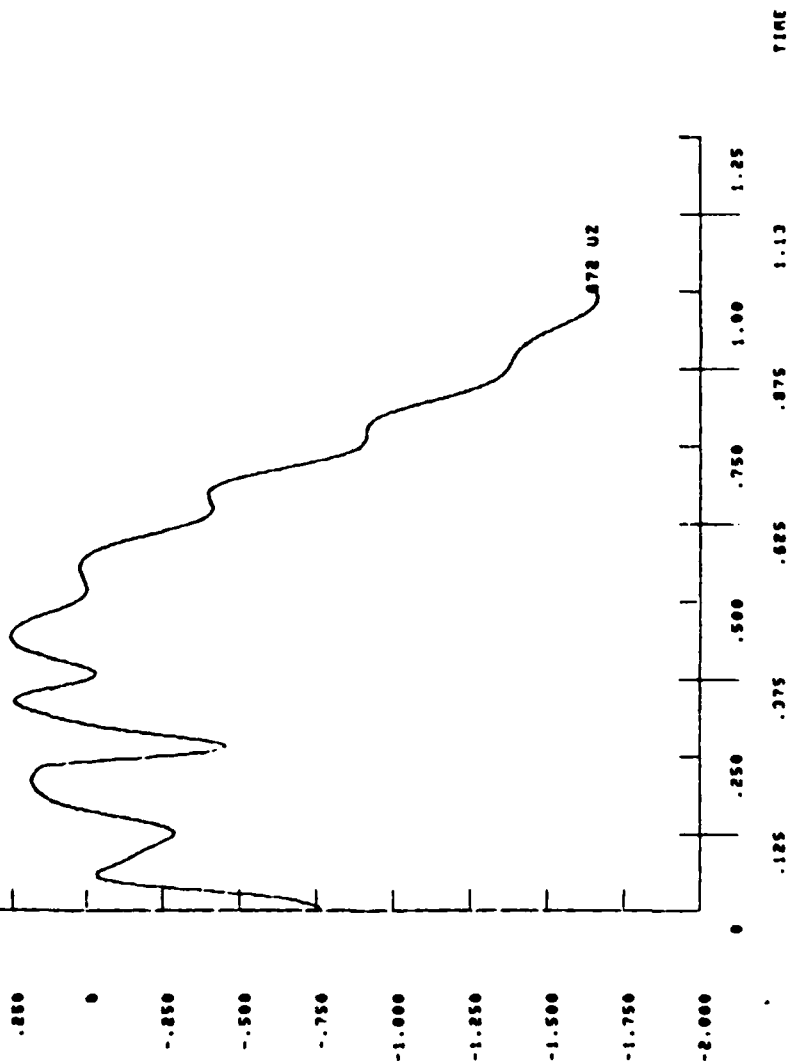
PART TYPE IDENTIFIERS NAME MINIMUM AT TIME MAXIMUM AT TIME

2 316P UZ 872 UZ -1.665 0.9900 0.8584 0.4410

PLOT DEFINITION

CURVE VARIABLE NAME

1 2 872 UZ



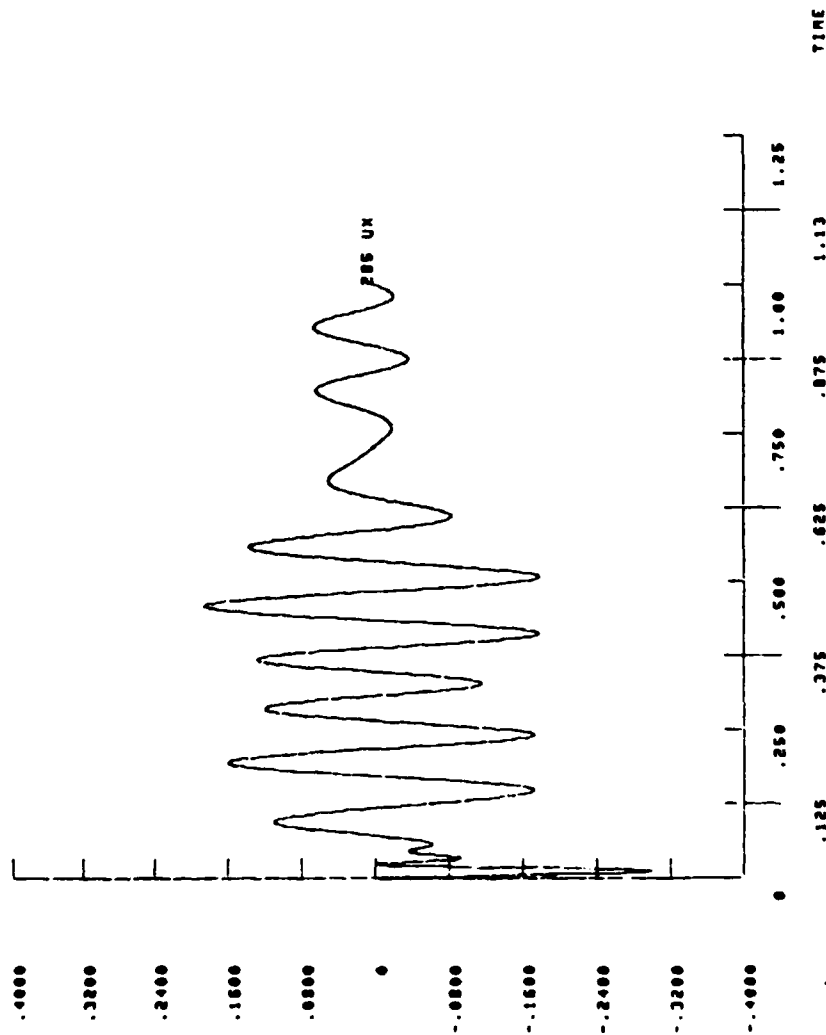
1 LUMB-0.0 CASE, PROOF LOADS-C.R.ORTLOFF

PROBATION COMPLETE FOR 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES

| VARIABLE IDENTIFIERS | NAME | MINIMUM | AT TIME | MAXIMUM | AT TIME |
|----------------------|--------|---------|------------|---------|---------|
| 2 810P 285 UX | 285 UX | -0.3003 | 0.1300E-01 | 0.1853 | 0.4500 |

PLOT DEFINITION
CURVE VARIABLE 285 UX



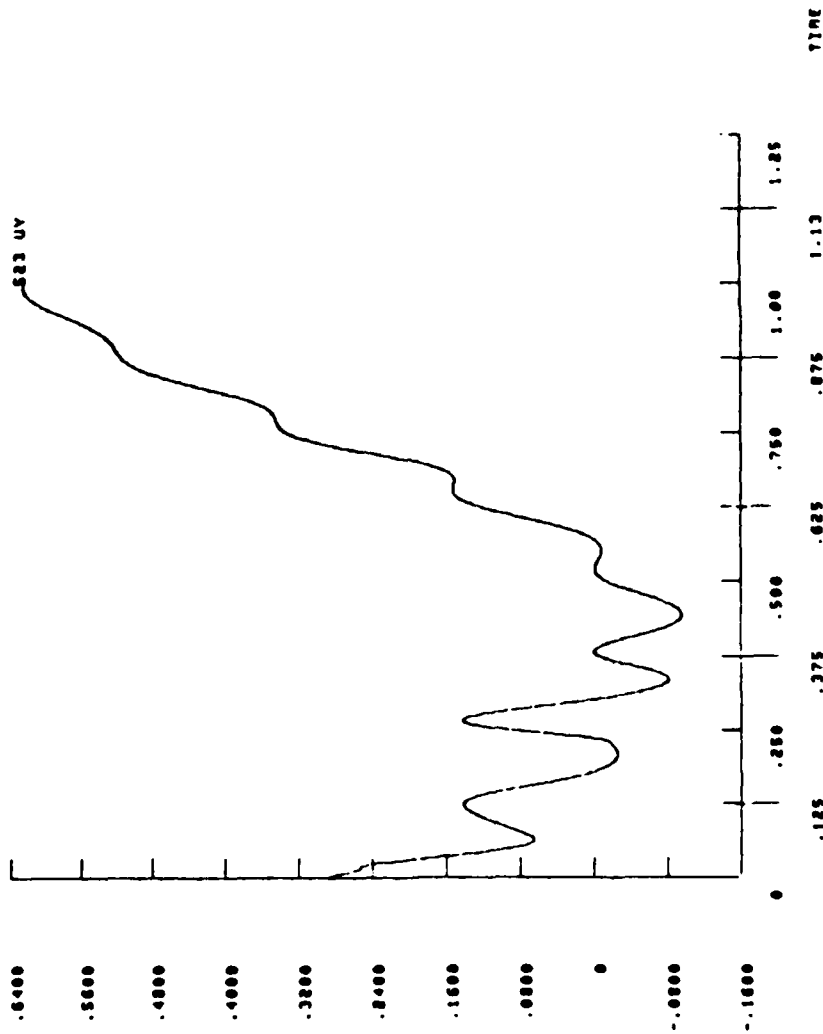
1 LUND-9.0 CASE, PROOF LOADS-C.R.ORTLOFF

POST26
ZU-1
0187-1.43

POORREIDCOMPLETE FOR 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES
 VARIABLE IDENTIFIERS NAME MINIMUM AT TIME MAXIMUM AT TIME
 2 DISP VALU UV 523 UV -0.9548E-01 0.4430 0.0846 0.9910

PLOT DEFINITION
 CURVE VARIABLE NAME
 1 2 523 UV



1 LUND-0,0 CASE,PROOF LOADS-C.A.ORTLOFF

POST26
 ZU-1
 DISP-1.43

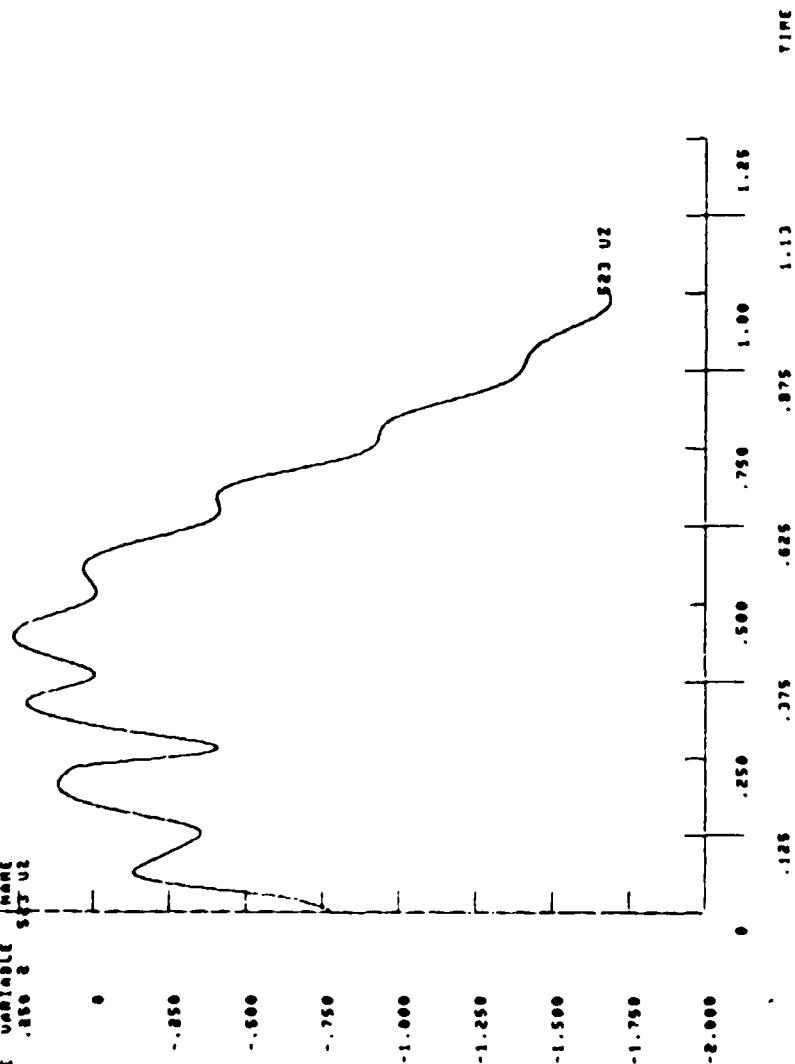
11P-0.523 UZ
 POST26-IMP.
 VARIABLE 2 IS 523 UZ PHASE REV. 0
 POST26-IMP.
 PLVAR,2

STORAGE COMPLETE FOR 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES
 NAME TYPE IDENTIFIERS NAME MINIMUM AT TIME MAXIMUM AT TIME

| NAME | TYPE | IDENTIFIERS | NAME | MINIMUM AT TIME | MAXIMUM AT TIME |
|-----------------|--------|-------------|------|-----------------|-----------------|
| 2 012400 523 UZ | 523 UZ | | | -1.000 | 0.0000 |
| | | | | 0.2703 | 0.4400 |

PLOT DEFINITION
 CURVE VARIABLE NAME
 1 .250 2 523 UZ

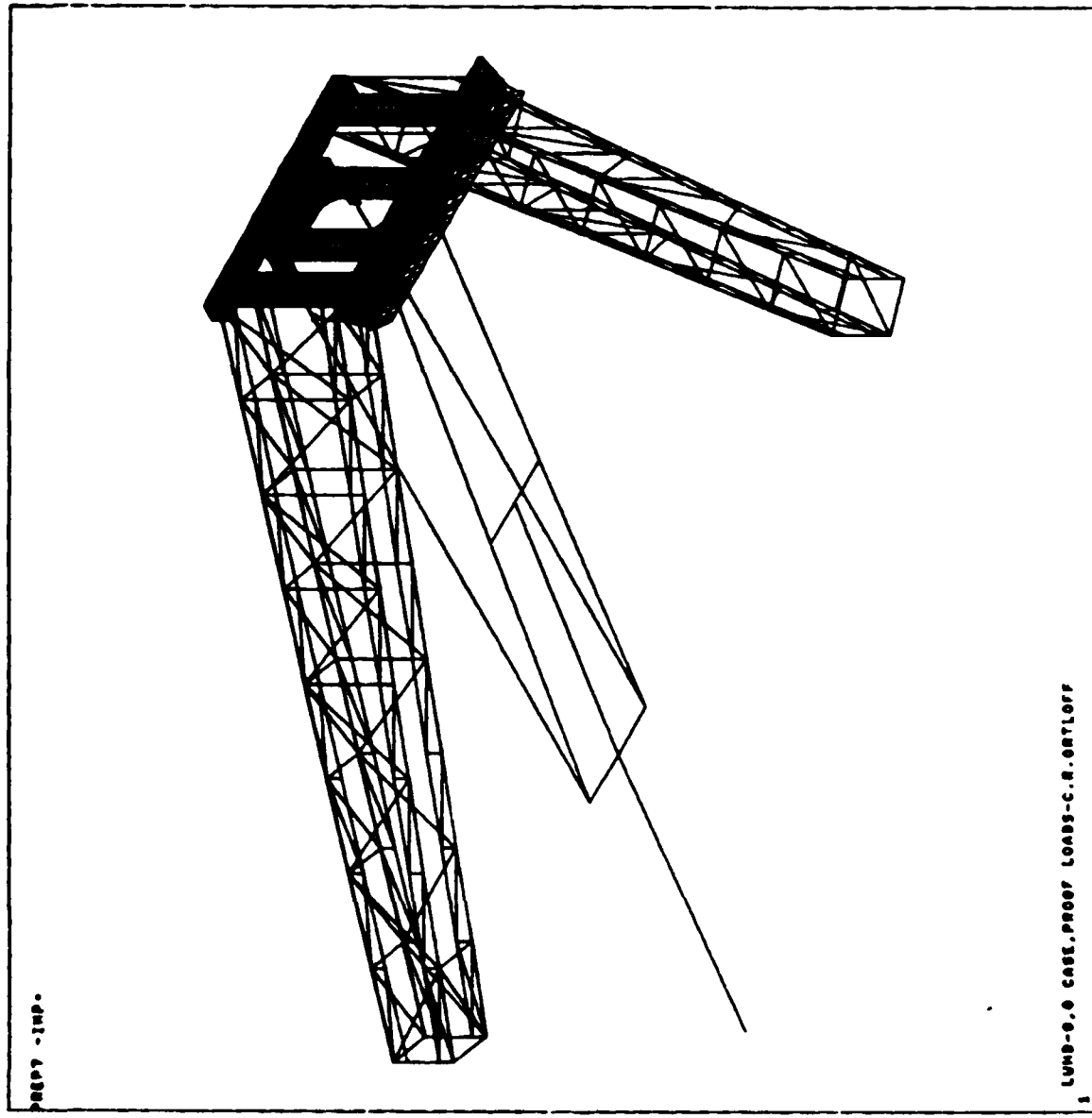


1 LUMB-0.0 CASE, PROOF LOADS-C.R.ORTLOFF

POST26
 2U-1
 0157-1.30

ANSYS 4.20
 DEC 5 1988
 10:20:04
 PREP7 ELEMENTS

NU--1
 VU--1
 20--1
 2107-100
 KP=50
 VF=30.0
 ZF=100



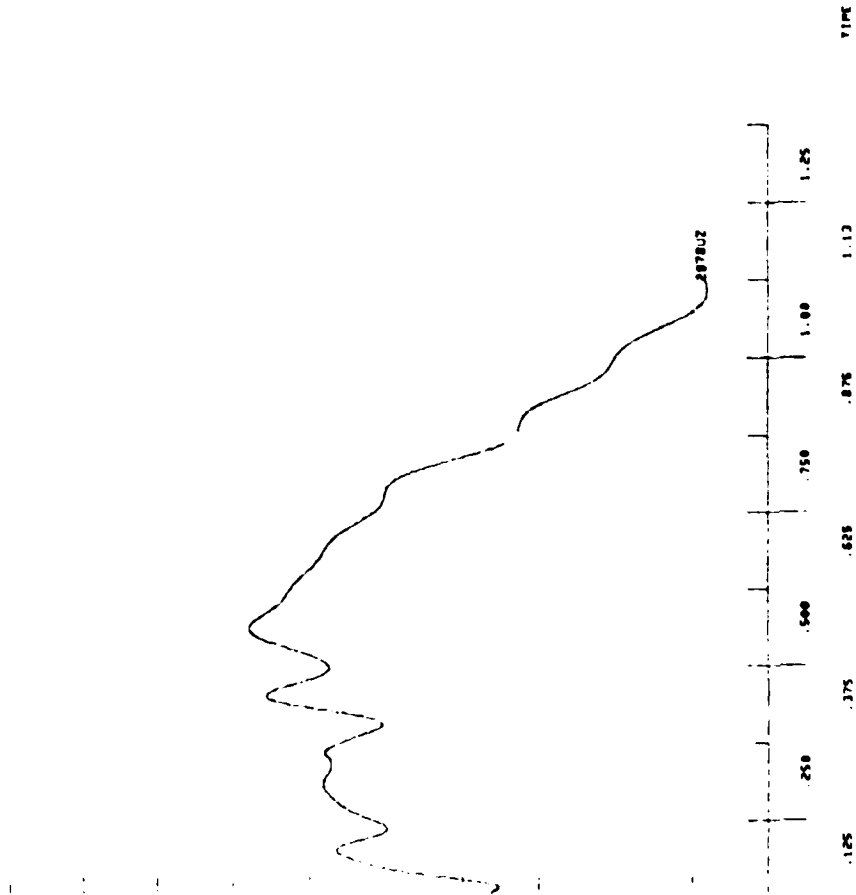
PREP7 -IMP.

1 LUND-0.0 CASE,PROOF LOADS-C.R.ORTLOFF

NAME: J
 POSTED: J
 FOR: J
 TIME: J
 NAME: J
 TIME: J
 NAME: J
 TIME: J

UNIT

3.000
 2.000
 1.000
 .000
 -1.000
 -2.000
 -3.000
 -4.000
 -5.000



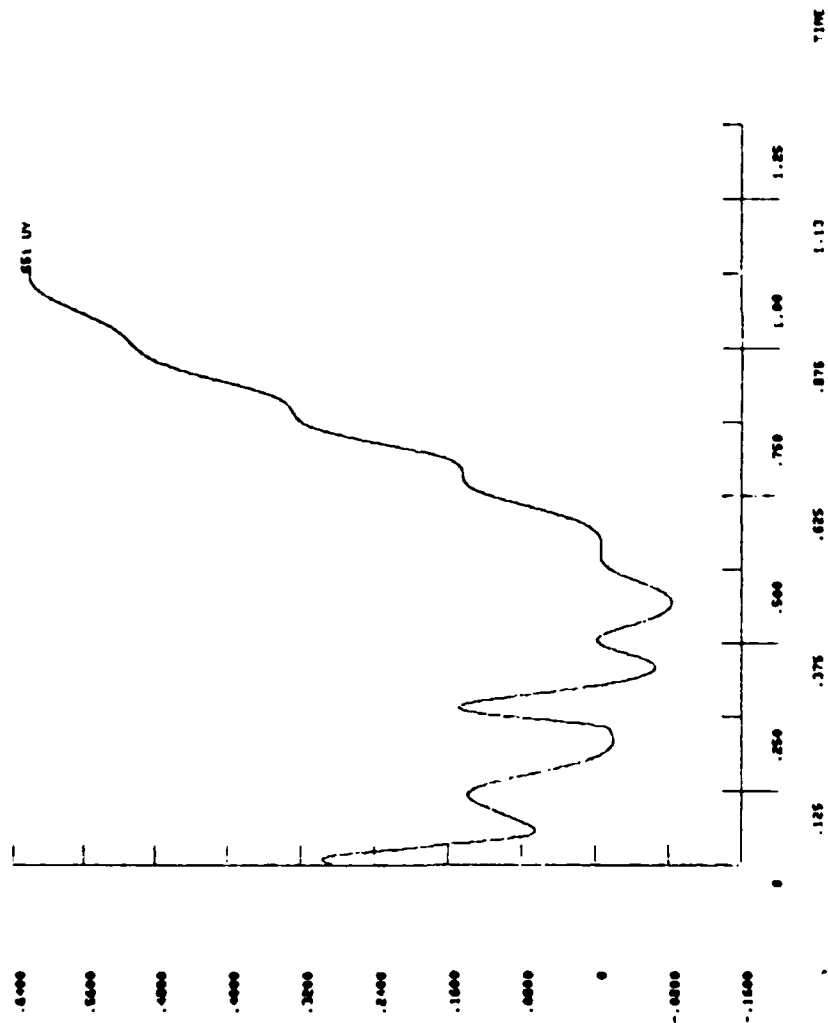
UNIT: 0.0 CASE: 00000 LOADS: C. R. 001000

POSTED:
 TIME:
 NAME:

LUMP-0
 POSTER-100
 POSTER COMPLETE FOR 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES
 NAME TYPE IDENTIFIERS NAME MINIMUM AT TIME MAXIMUM AT TIME
 0 0100 001 UV 001 UV -0.0306E-01 0.4430 0.0000 0.0940

PLOT DEFINITION VALU
 NAME VARIABLE NAME
 1 001 UV



LUMP-0, 0 CASE, PROOF LOADS-C.R. ONTLOFF

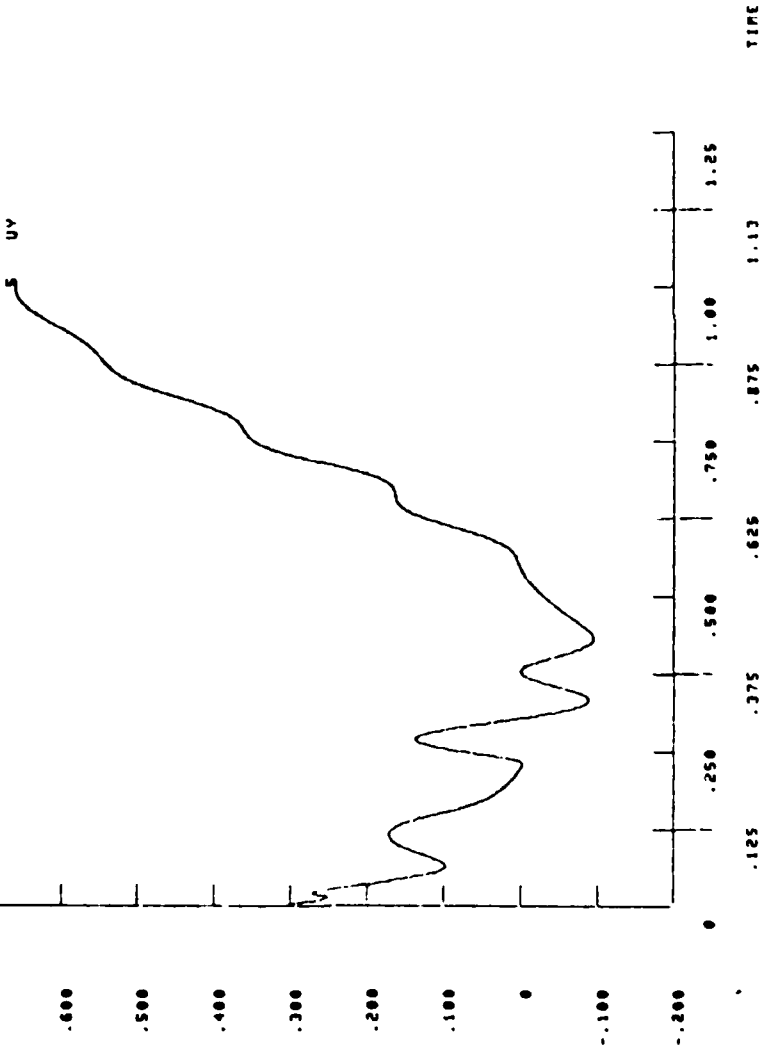
POSTER
 20-1
 0107-1.43

POST26-IMP.
 VARIABLE 2 IS S UV PHASE KEY= 0
 POST26-IMP.
 PLVAR,2

STORAGE COMPLETE FOR 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES
 VAR TYPE IDENTIFIERS NAME MINIMUM AT TIME MAXIMUM AT TIME
 2 816400 S UV -0.9426E-01 0.4320 0.6633 0.9970

PLOT DEFINITION
 CURVE VARIABLE NAME
 1 .700 2 S UV



1 LUMD-0.0 CASE, PROOF LOADS-C.R.ORTLOFF

POST26
 ZU=1
 DIST=1.38

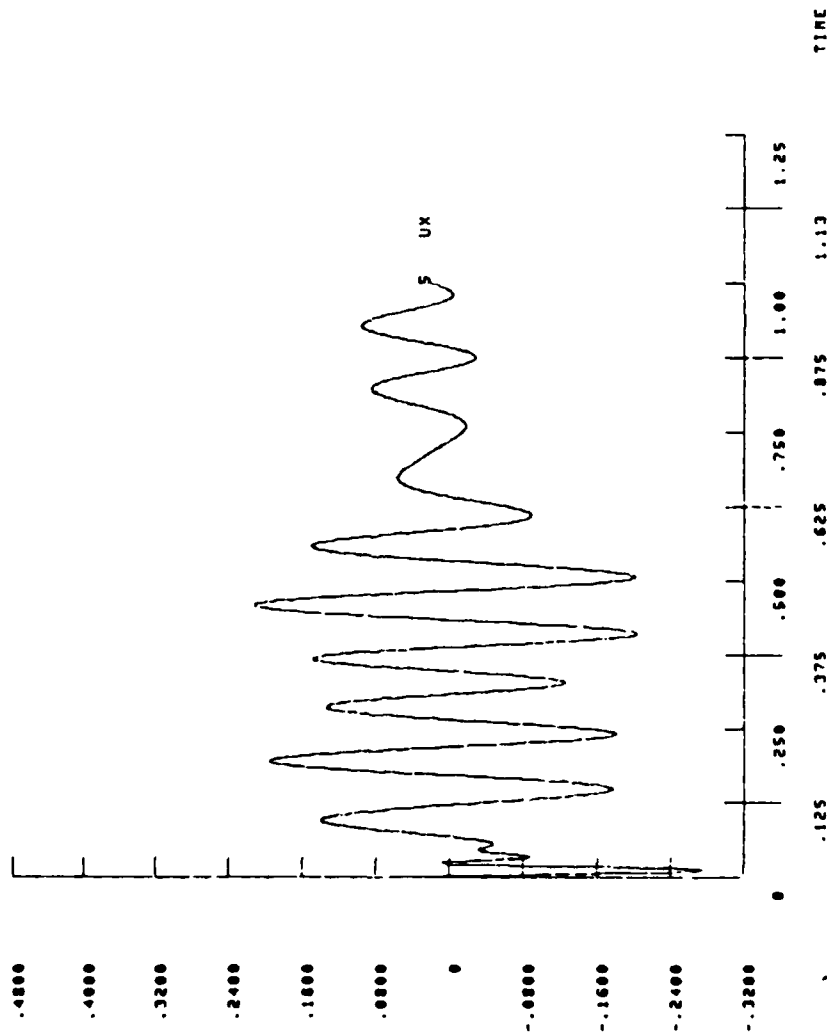
| SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES | | | |
|--|-------------|---------|---------|
| NAME | IDENTIFIERS | MINIMUM | AT TIME |
| NAME | IDENTIFIERS | MINIMUM | AT TIME |

| | | | | | | | |
|--------|----|---|----|---------|------------|--------|--------|
| 2 DISP | UX | 5 | UX | -0.2760 | 0.1300E-01 | 0.2130 | 0.4580 |
| UX | UX | | | | | | |

| NAME | DEFINITION |
|------|------------------|
| UX | CURVE VARIABLE 2 |
| S | 1 |

| NAME | DEFINITION |
|------|------------------|
| UX | CURVE VARIABLE 2 |
| S | 1 |

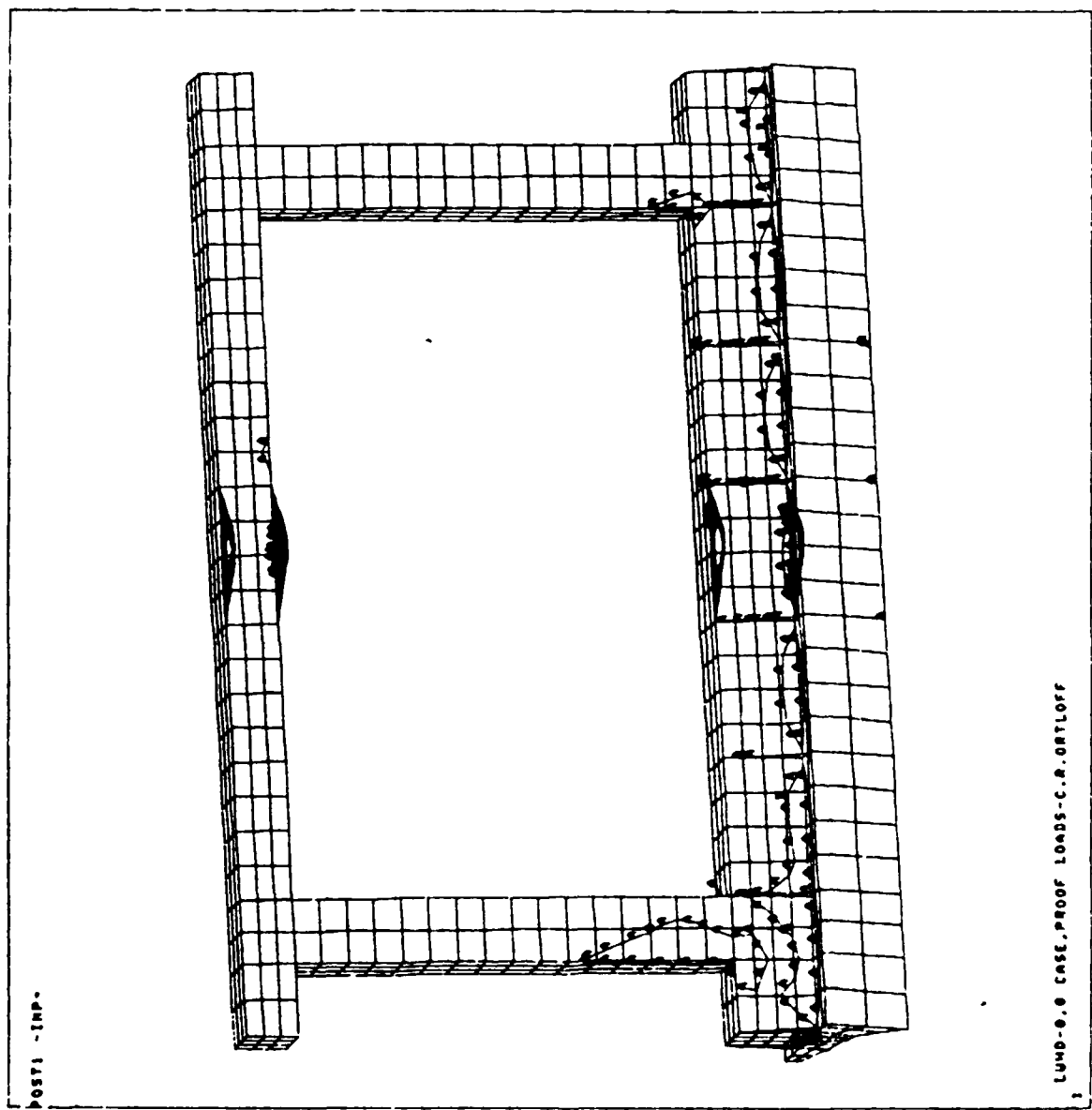
L
0084



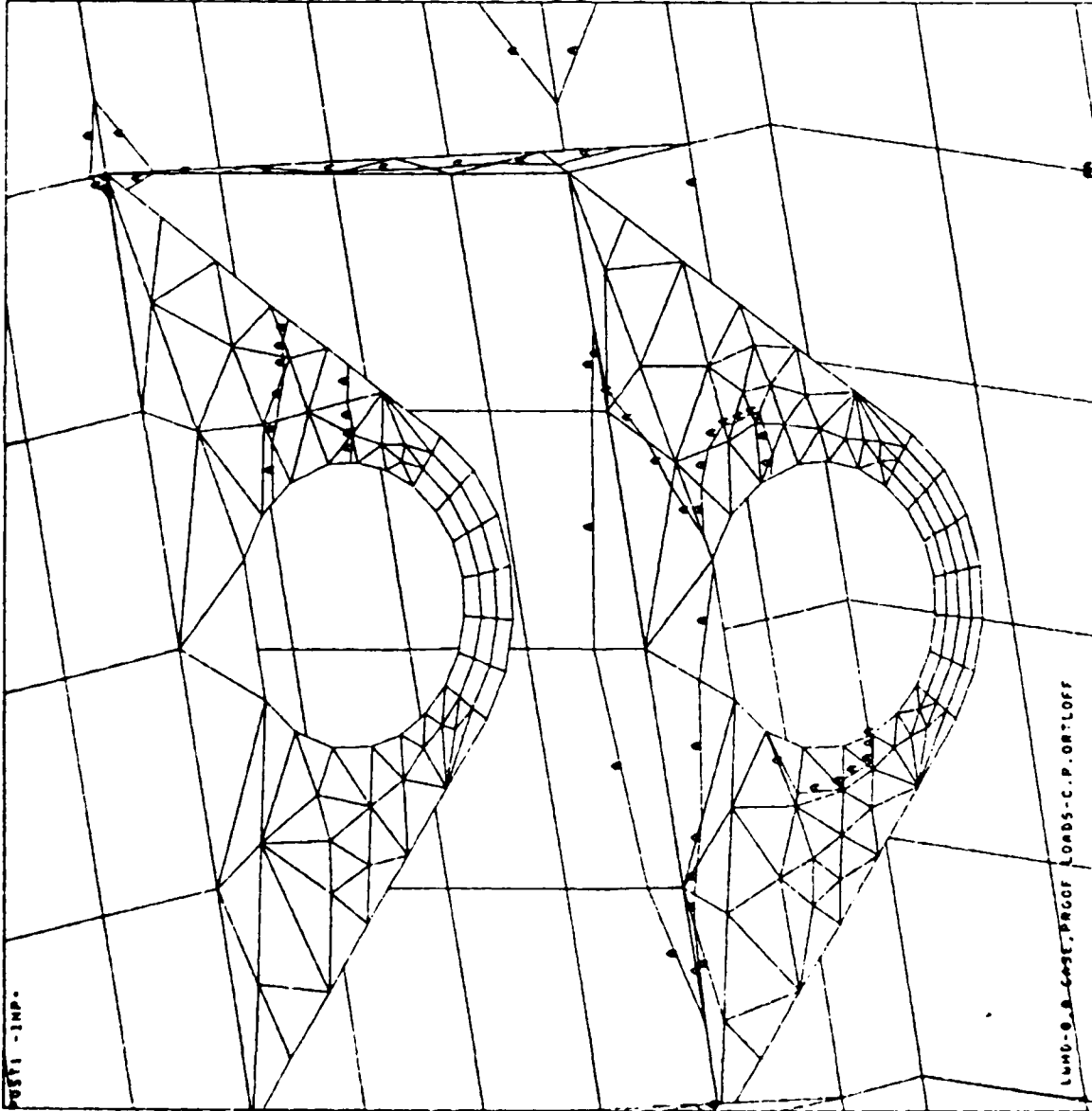
LUMB-O, O CASE, PROOF LOADS-C.R. ORYLOFF

POST 26
ZU-1
DIST-1.43

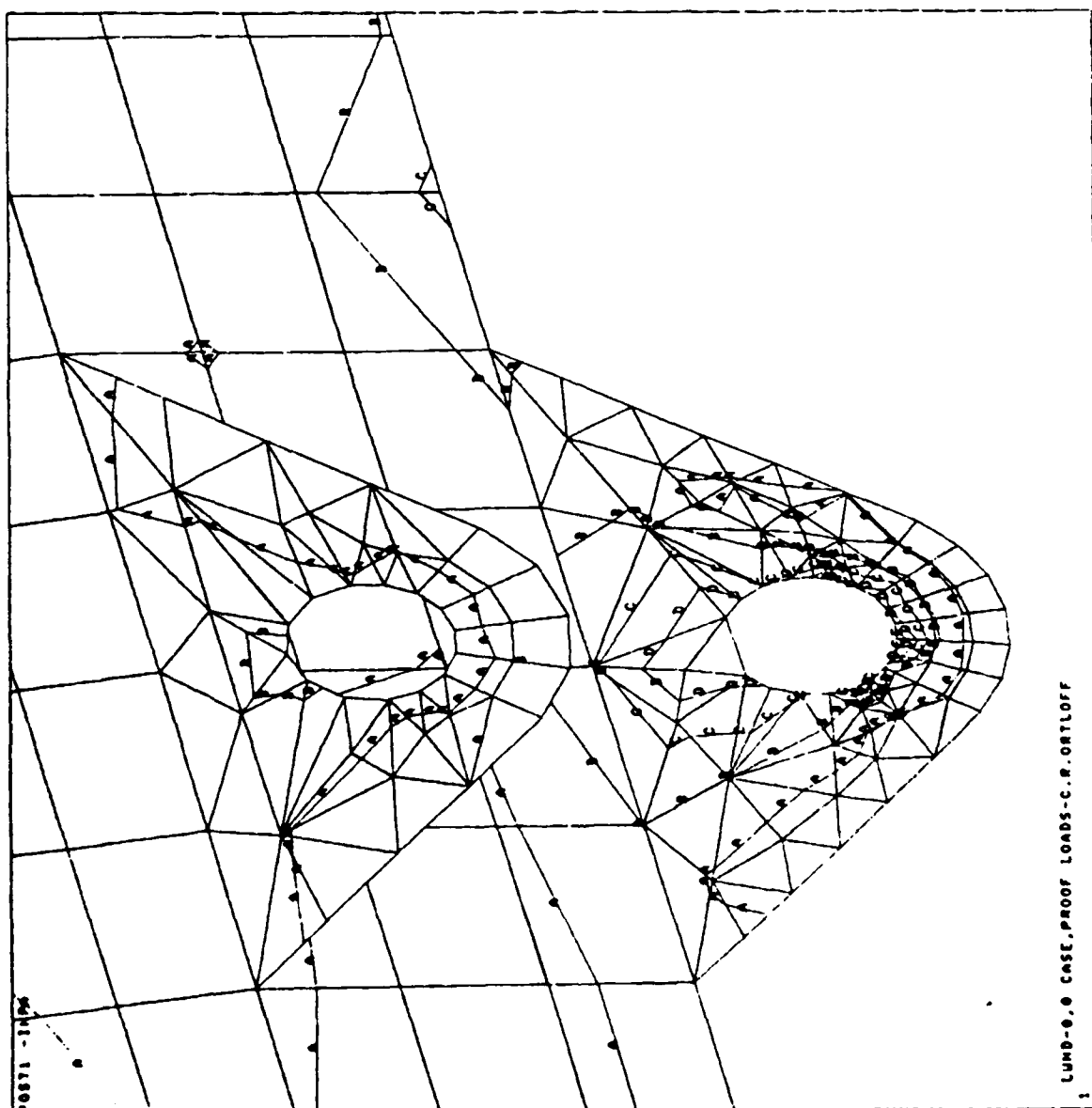
ANSYS 4.20
 DEC 5 1986
 16115101
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.488
 SICE
 TOP
 XU=.2
 VU=.3
 ZU=.1
 DIST=59.3
 XF=82.9
 VF=26.6
 ZF=6.46
 WIDEN
 MX=46280
 MY=59.9
 A=7162
 B=15466
 C=23170
 D=30874
 E=38578



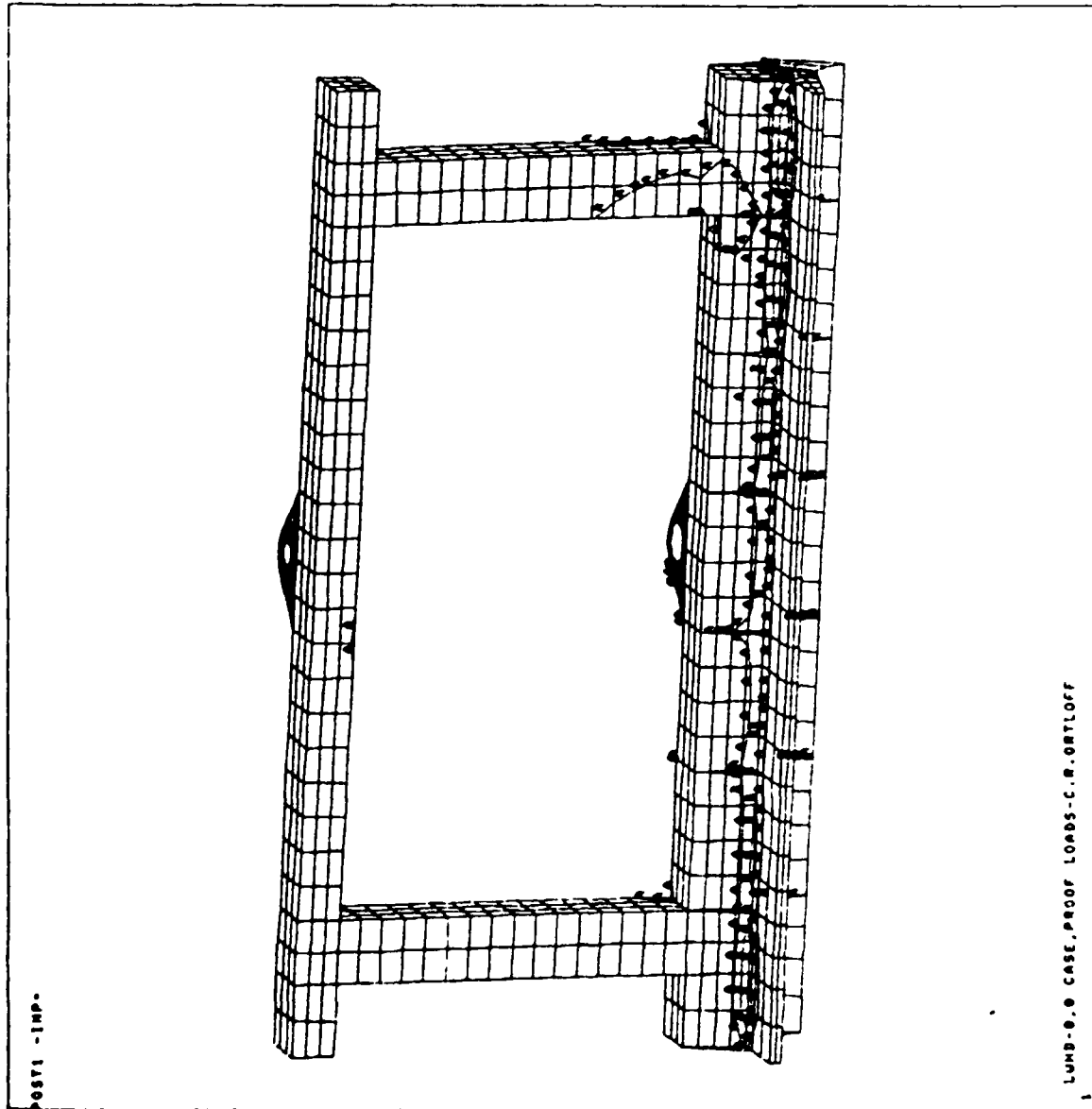
ANSV 4.28
 DEC 6 1986
 16:31:38
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.428
 SICE
 TOP
 ZOOM
 XU=.2
 VU=1
 ZU=-1
 1 DIST=36.6
 2 XF=53.6
 3 VF=11.7
 4 ZF=-10.1
 XRT0=4.22
 VRT0=4.91
 HIDDEN
 MX=40112
 MY=0
 A=7762
 B=15466
 C=23170
 D=30874
 E=38578



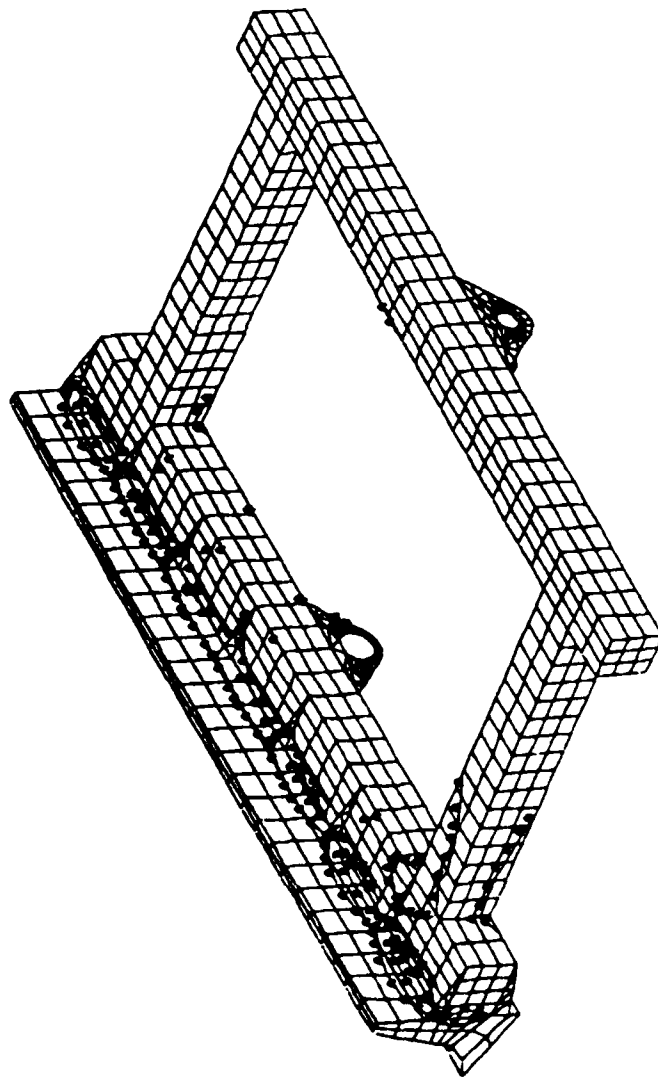
ANSYS 4.20
 DEC 6 1986
 16137100
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.428
 SICE
 TOP
 ZOOM
 XU=.2
 YU=1
 ZU=-1
 Z DIST=54.6
 Z XF=47.2
 Z VF=42.7
 Z ZF=18.8
 XRT0=4.22
 YRT0=8.39
 HIDDEN
 MX=17334
 MY=0
 A=2947
 B=5836
 C=8725
 D=11614
 E=14593



ANSYS 4.28
 DEC 5 1986
 16:00:52
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.428
 SIZE
 TOP
 ZOOM
 RV=.2
 VU=.3
 ZU=1
 DIST=72
 RF=52.4
 VF=27.3
 ZF=2.89
 XRT0=1.21
 HIDDEN
 RH=48280
 RM=50.0
 A=7762
 B=15466
 C=23170
 D=30874
 E=38578

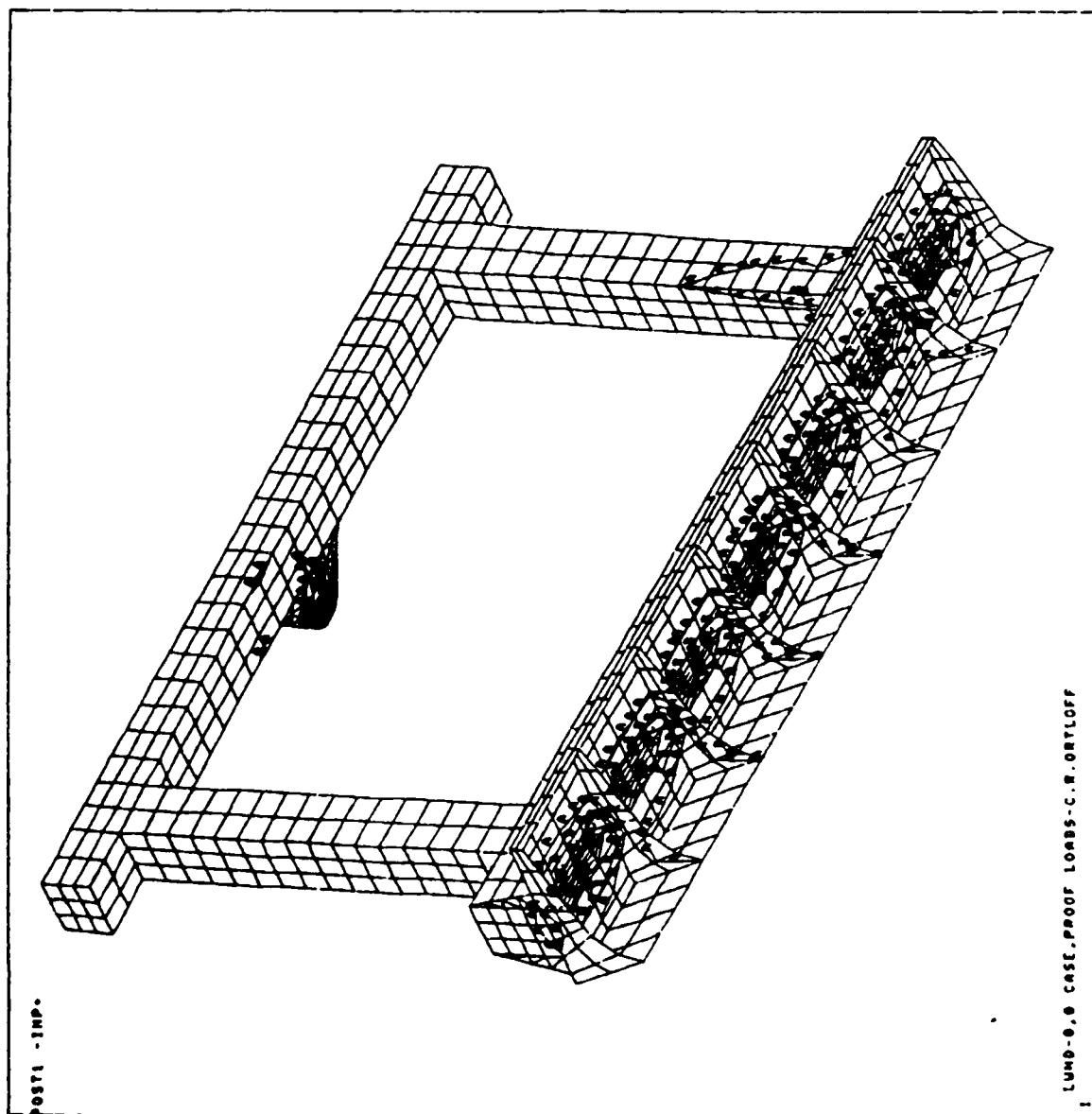


1000

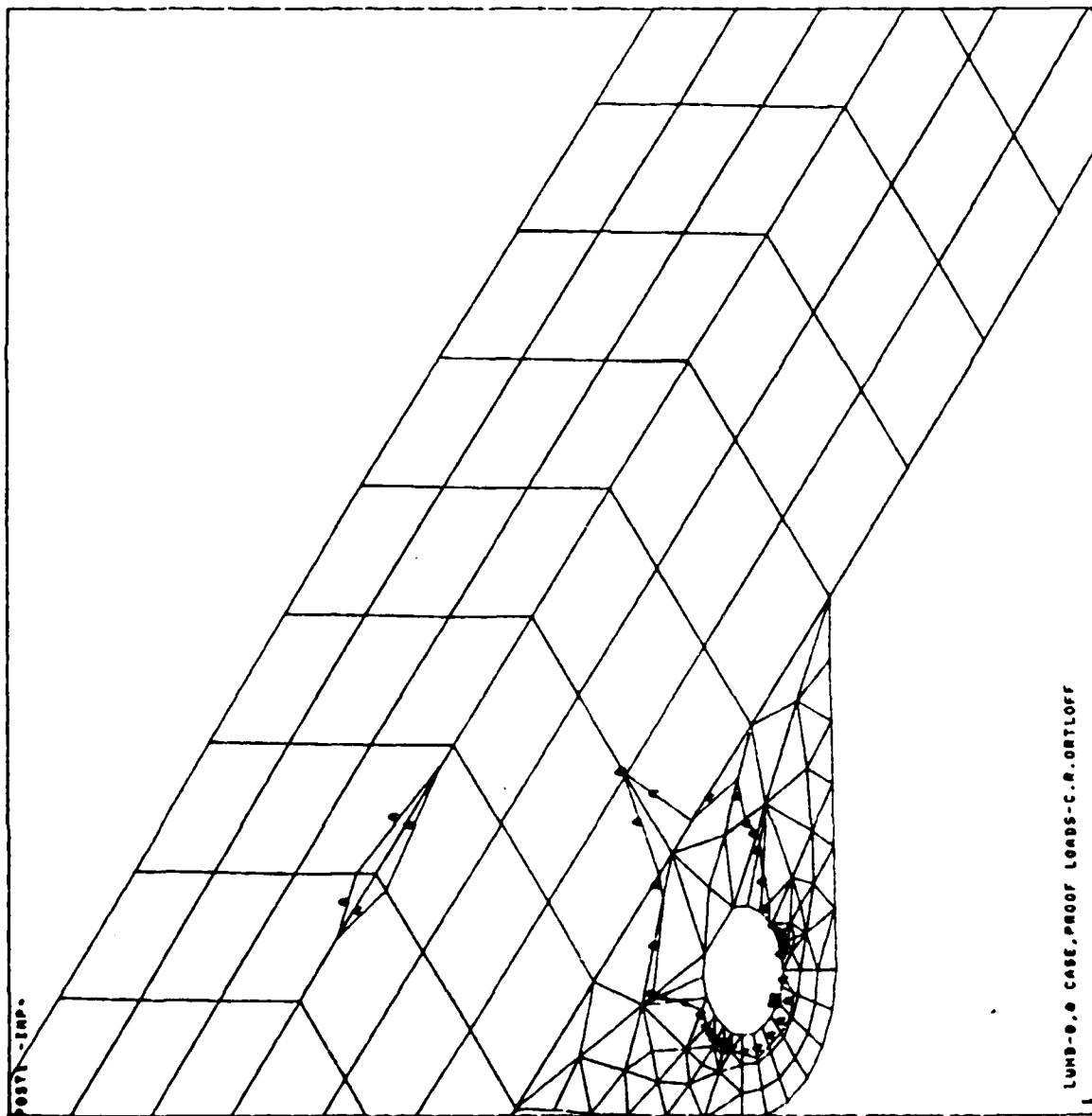


WFO-0,0 CASE, P0007 LONG-C. R. 0071077

ANSYS 4.08
 DEC 5 1986
 14100145
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.428
 SLICE
 TOP
 XU=-1
 VU=-1
 ZU=1
 DIST=59.2
 XF=54.2
 YF=26.4
 ZF=4.85
 HIDDEN
 MN=46280
 MM=59.9
 A=7782
 B=15466
 C=23170
 D=30874
 E=38578

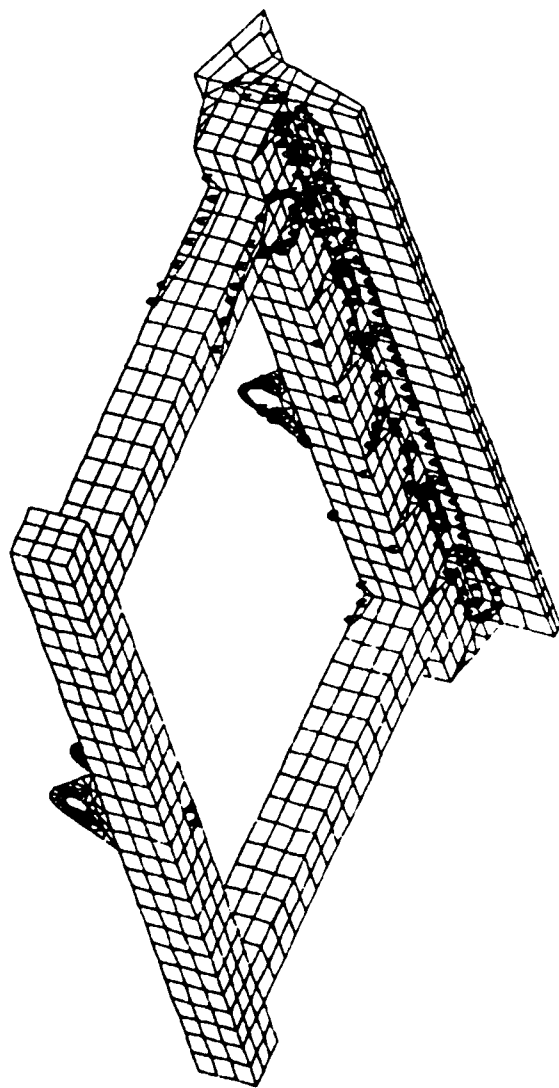


ANSYS 4.20
 DEC 5 1986
 14109146
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.428
 SICE
 TOP
 ZOOM
 KU=-1
 VU=-1
 ZU=1
 E BIST=11.6
 E XF=45.2
 E VF=47.9
 E 2F=17.3
 VRT0=1.06
 HIDDEN
 RX=17334
 RM=8
 A=7762
 B=15466



BOTTOM TAB

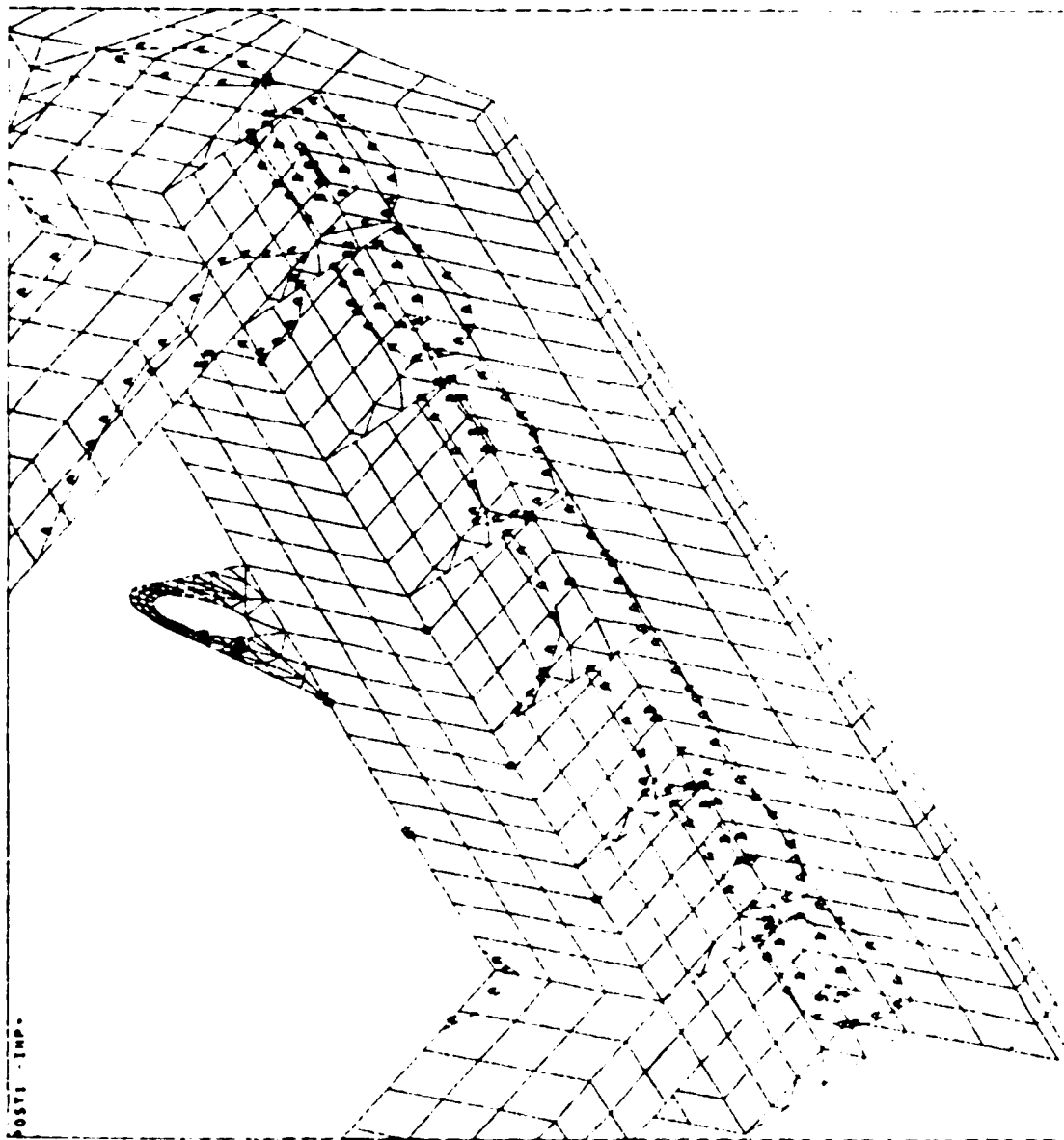
ANSYS 4.20
 DEC 5 1986
 14142131
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.488
 SICE
 TOP
 KU=1
 YU=.5
 ZU=.5
 D187=84.3
 HF=52.6
 VF=25.6
 ZF=5.21
 ANGL=60
 MIDDEN
 MX=46200
 MY=59.0
 A=7762
 B=15466
 C=23170
 D=30874
 E=38578



POST1 -IMP.

1 LUMB=0.0 CASE, PROOF LOADS-C.R. DRYLOFF

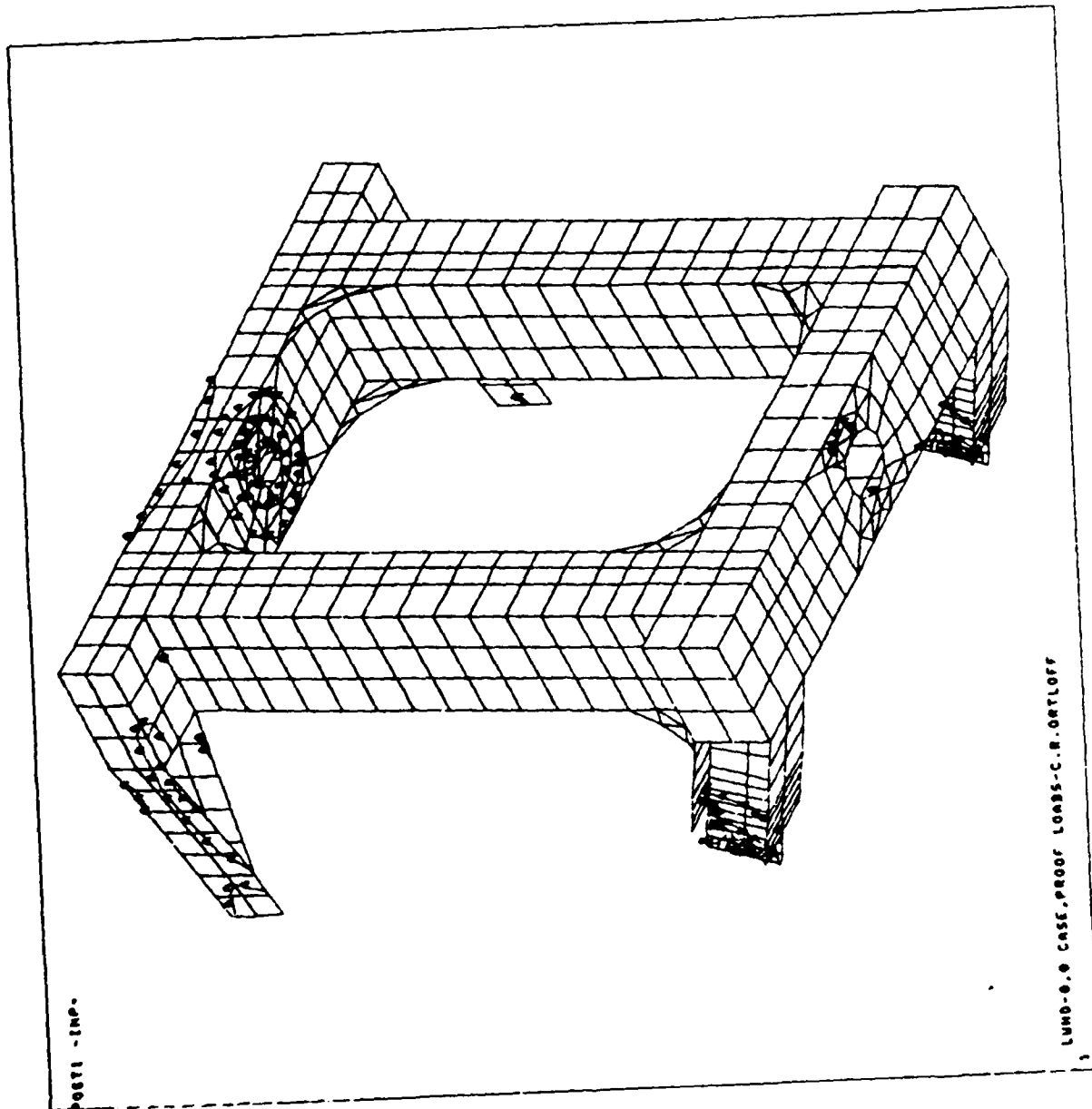
ANSYS 4.20
 DEC 5 1986
 14142131
 POST1 STRESS
 STEP=1
 TIME=1
 TIME=1.428
 SICE
 YOP
 ZOOM
 KU=1
 VU=.5
 ZU=.5
 DIST=34.4
 KF=59.8
 VF=4.68
 ZF=11.8
 ANGL=60
 VRTO=1.65
 MIDDEN
 RK=46280
 RM=0
 A=7762
 B=15456
 C=23170
 D=20874
 E=20578



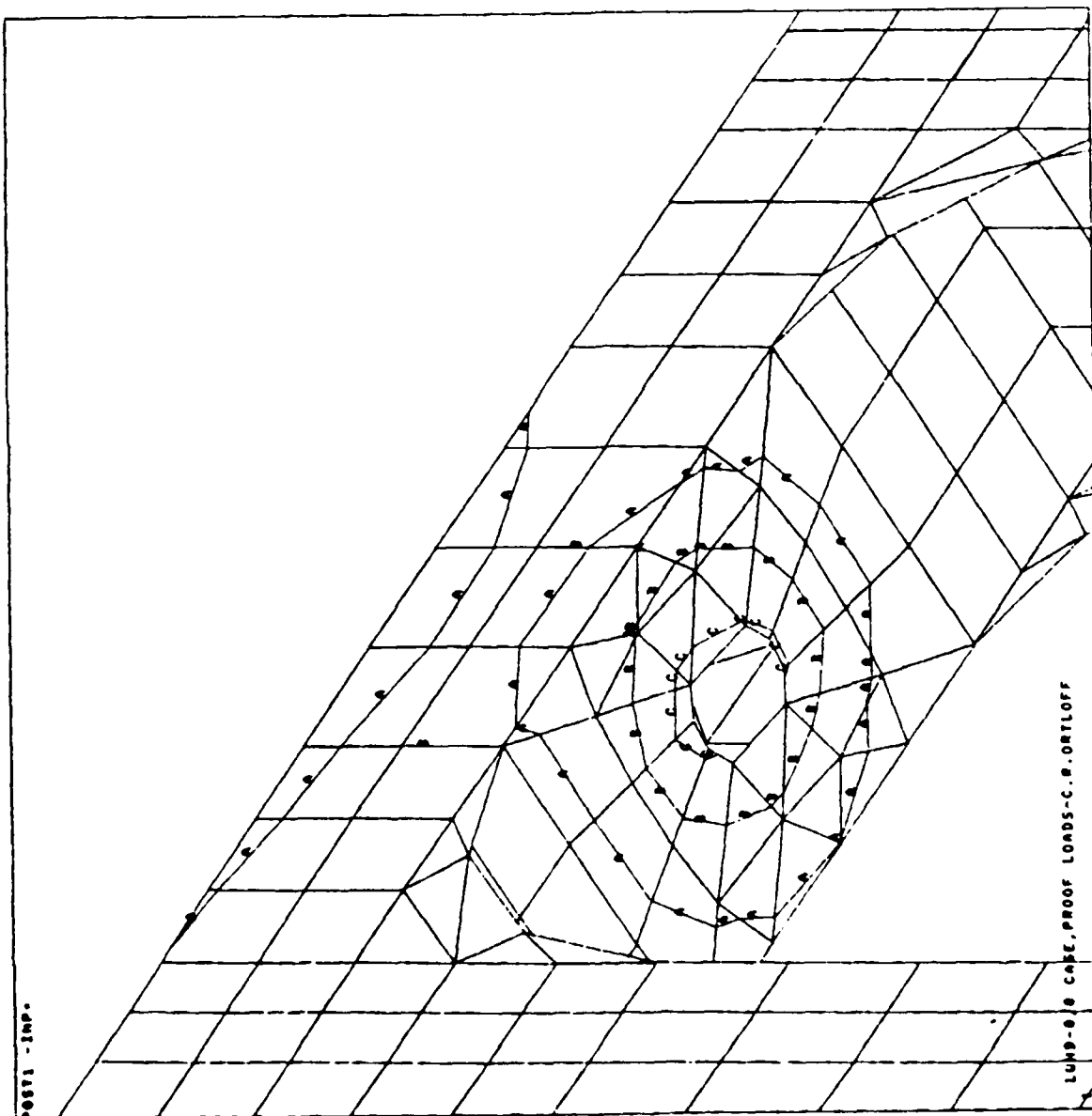
LUND-0.0 CASE.PRCOF LOADS-C.D.ORTLOFF

ANSYS 4.20
 DEC 5 1980
 14132158
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.420
 SLOC
 TOP
 KU=-1
 YU=-1
 ZU=1
 DIST=32.7
 XF=51.5
 VF=35.2
 ZF=-8.87
 MIDDLEM
 RK=48474
 RM=220
 A=7112
 B=14006
 C=20000
 D=27794
 E=34080
 F=41582

GIMBAL

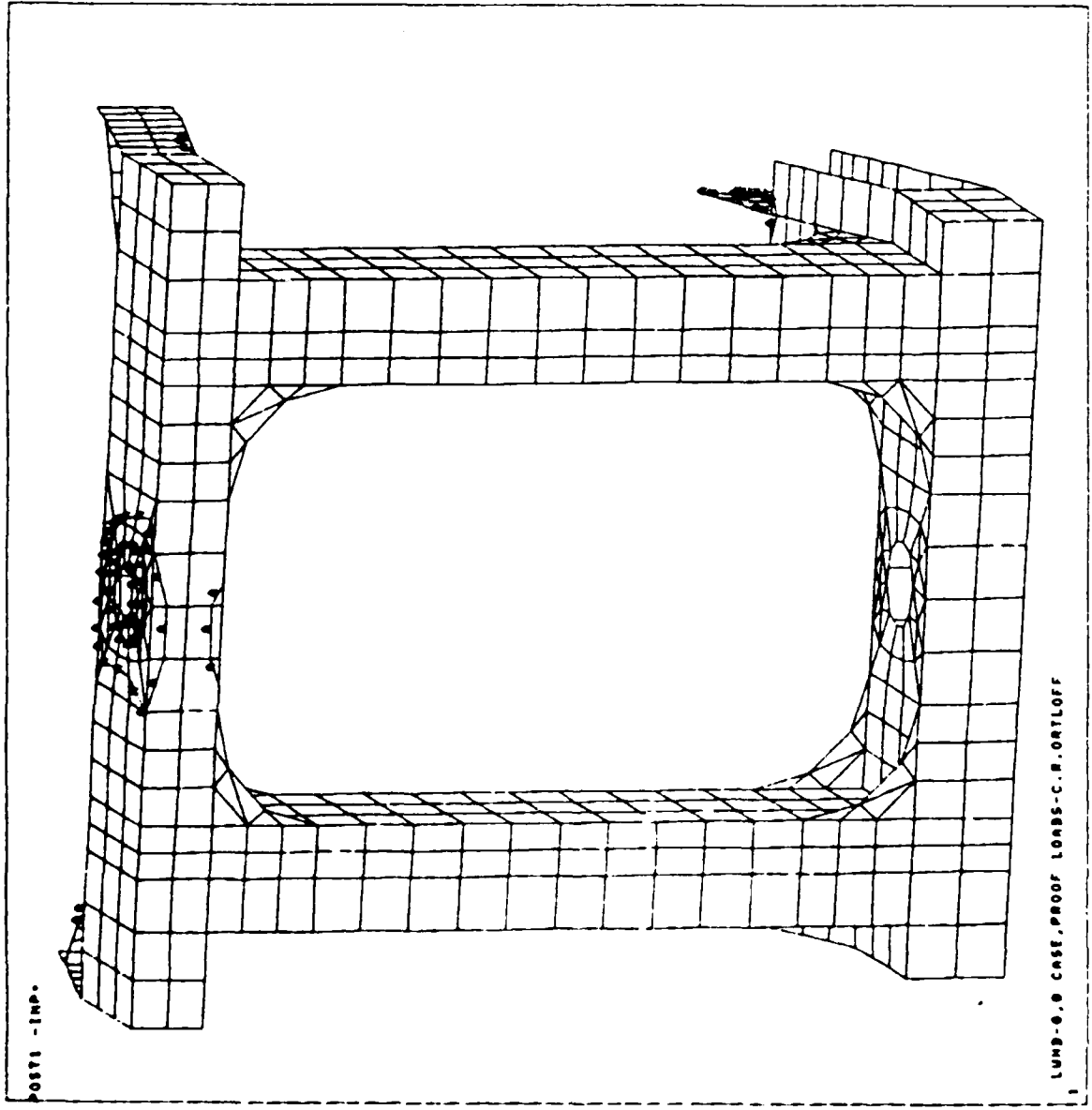


ANSYS 4.20
 DEC 5 1986
 14:32:52
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.488
 SLOC
 TOP
 ZOOM
 KU=-1
 VU=-1
 ZU=1
 F DIST=10.0
 F MF=49.2
 F VF=50.0
 C ZF=4.68
 VRT0=1.2
 HIDDEN
 MN=28230
 MN=0
 A=7112
 B=14006
 C=20900
 D=27794

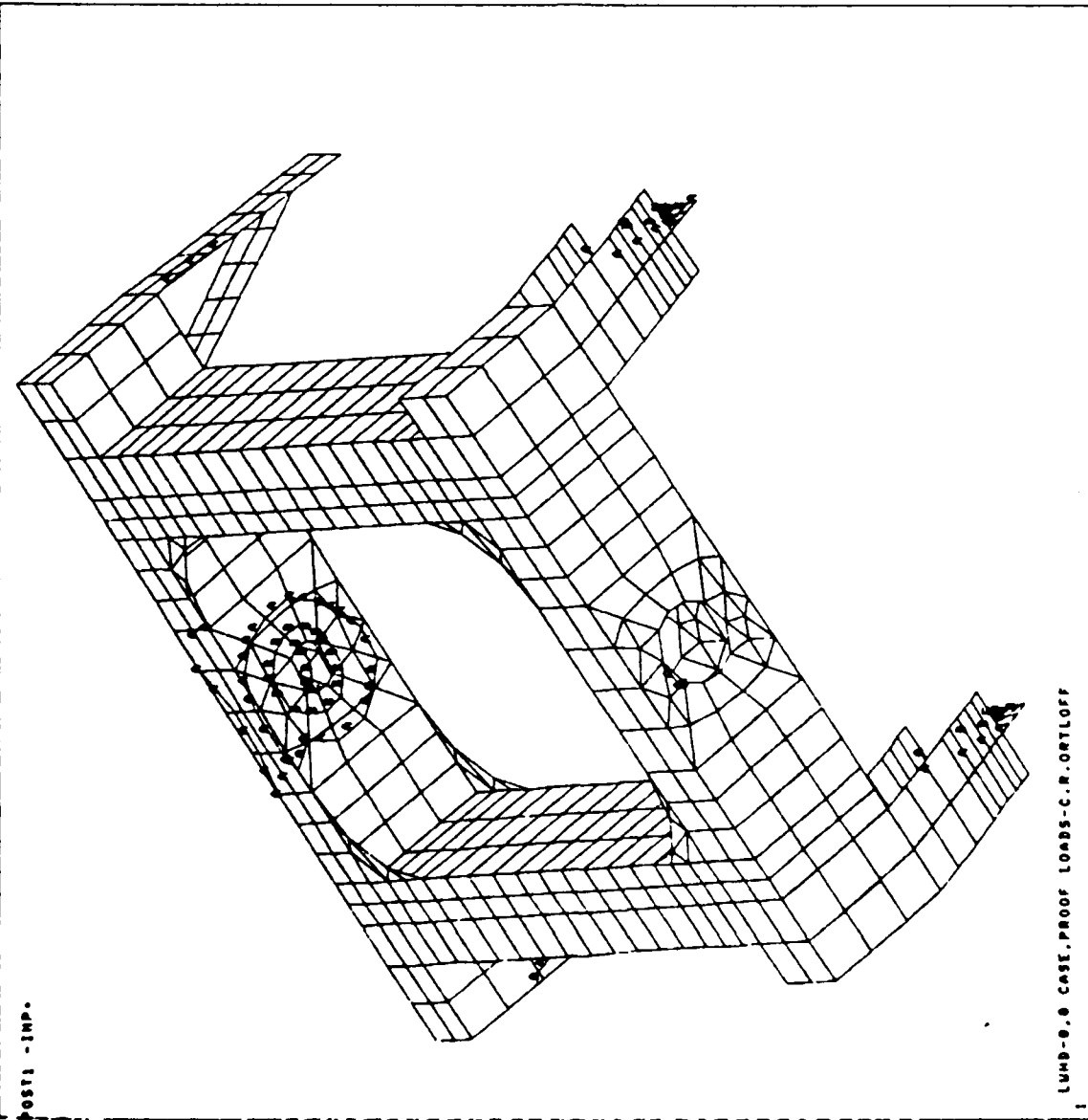


TOP
 GIMBAL

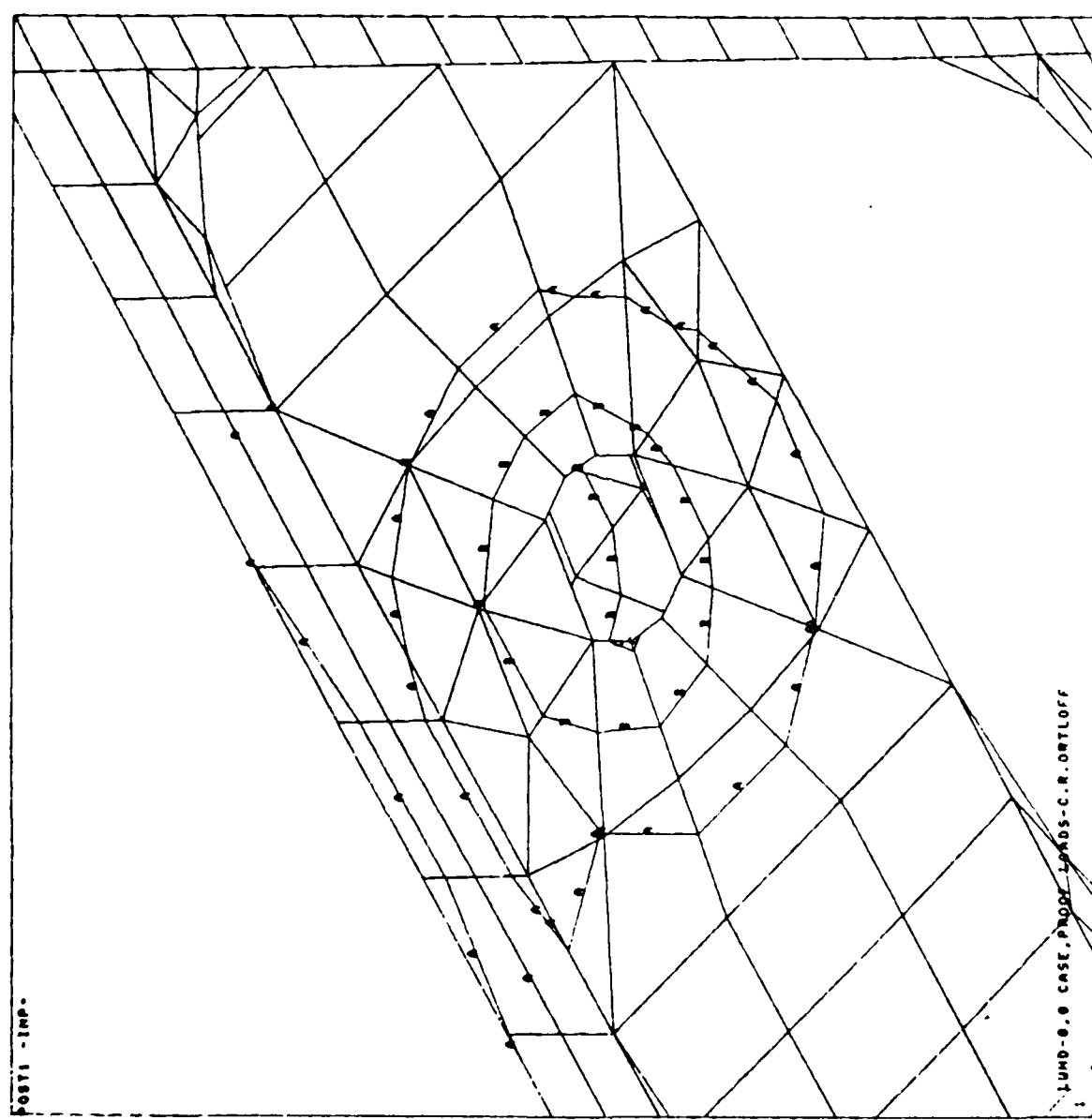
AMSVS 4.28
 DEC 5 1986
 15:20:49
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.428
 SICE
 TOP
 XV=.2
 YV=.3
 ZU=1
 DIST=28.1
 XF=53.3
 YF=31.9
 ZF=-8.53
 MIDDEN
 MX=48474
 MY=220
 A=8261
 B=16384
 C=24347
 D=32380
 E=48433



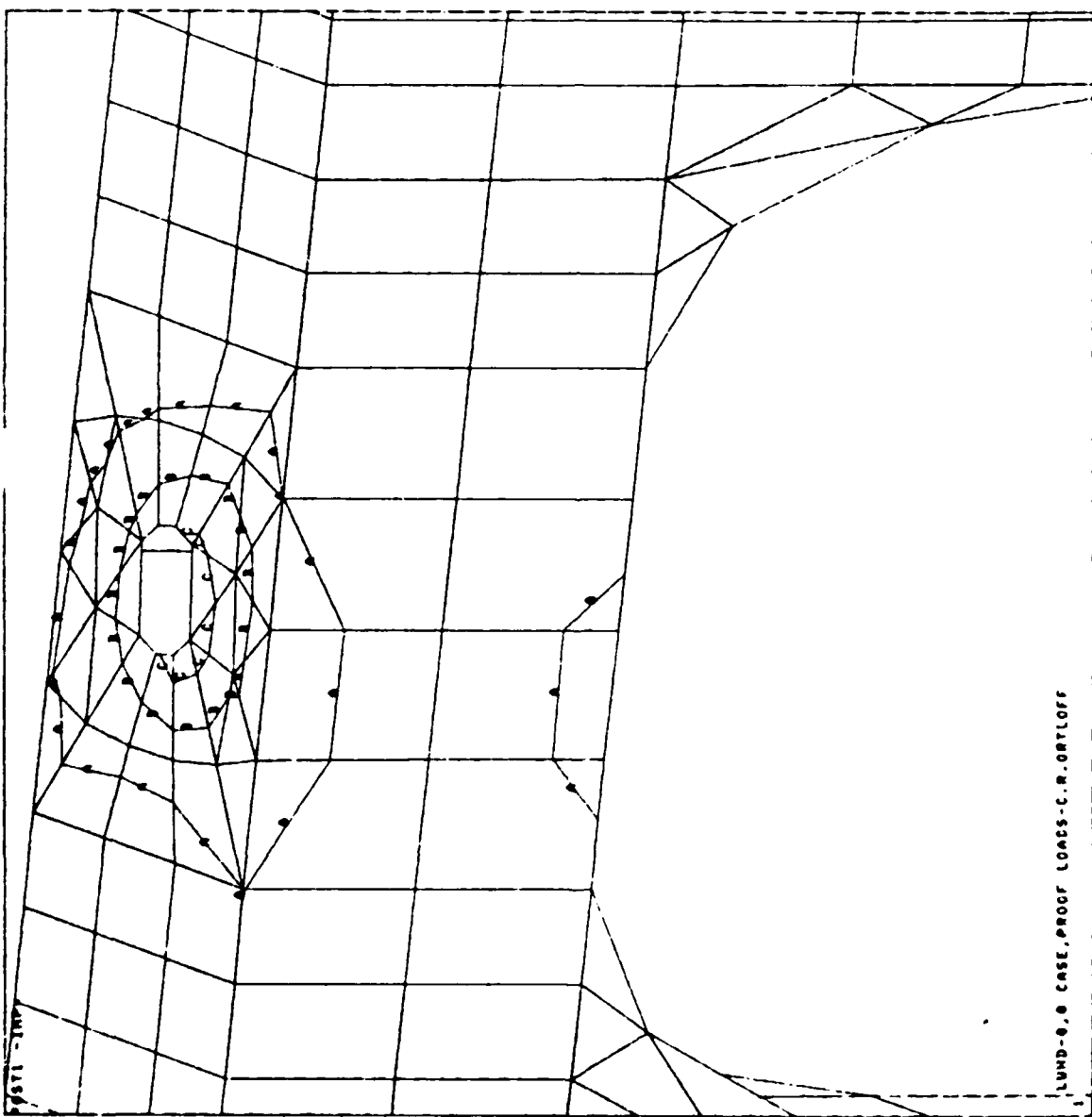
ANSYS 4.28
 DEC 5 1985
 15:43:40
 POST1 STRESS
 STEP=1
 LAYER=1
 TIME=.428
 SICE
 TOP
 XU=.3
 VU=-1
 ZU=.4
 DIST=30.2
 XF=54.6
 YF=33.1
 ZF=-7.74
 MIDDLEM
 MX=48474
 MY=220
 A=8851
 B=16384
 C=24347
 D=32380
 E=48433



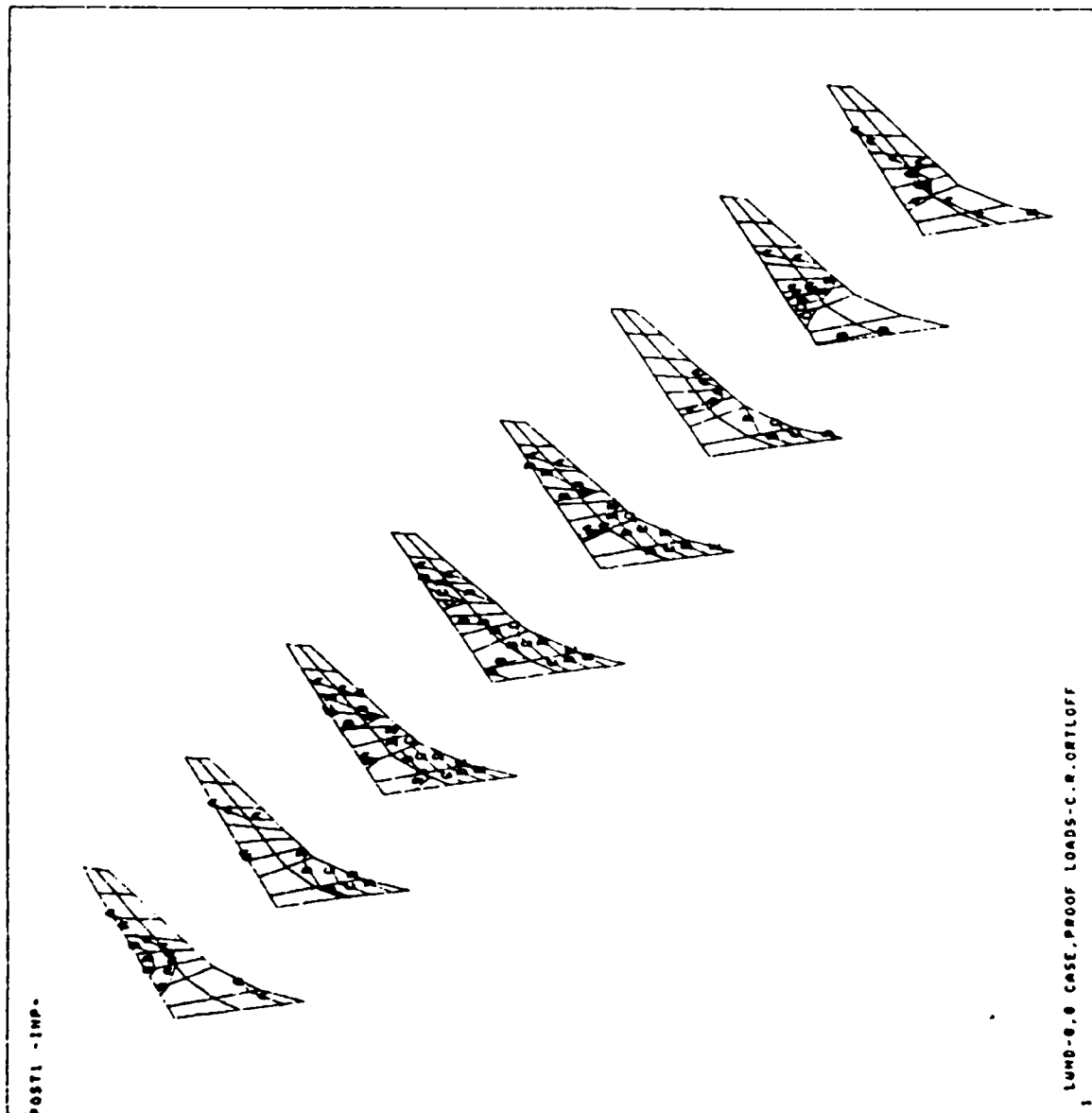
ANSYS 4.20
 DEC 5 1986
 15:43:40
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.428
 SICE
 TOP
 ZOOM
 KU=.3
 VU=-1
 ZU=.4
 8 DIST=9.47
 8 XF=57.7
 8 YF=38.7
 8 ZF=3.92
 XRT0=1.21
 HIDDEN
 RK=29230
 RN=0
 A=8261
 B=16304
 C=24347



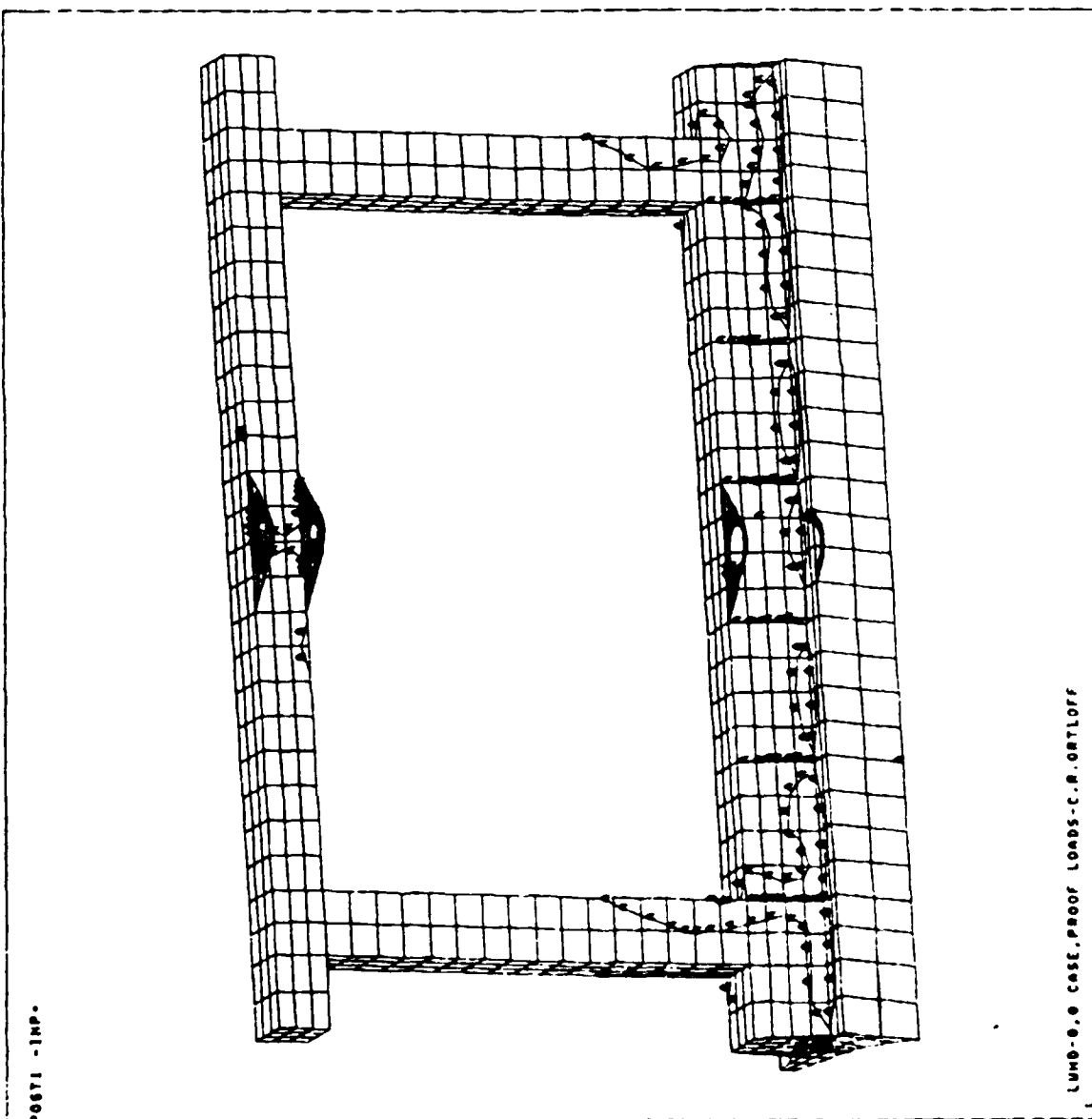
ANSYS 4.80
 DEC 6 1986
 15:20:40
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.428
 SICE
 TOP
 ZOOM
 NU=.2
 VU=.3
 ZU=1
 E DIST=11.4
 E XF=51.4
 E VF=48.3
 E ZF=-13.4
 VRTG=1.9
 MIDDLE
 MX=28230
 MY=0
 A=8261
 B=16304
 C=24347



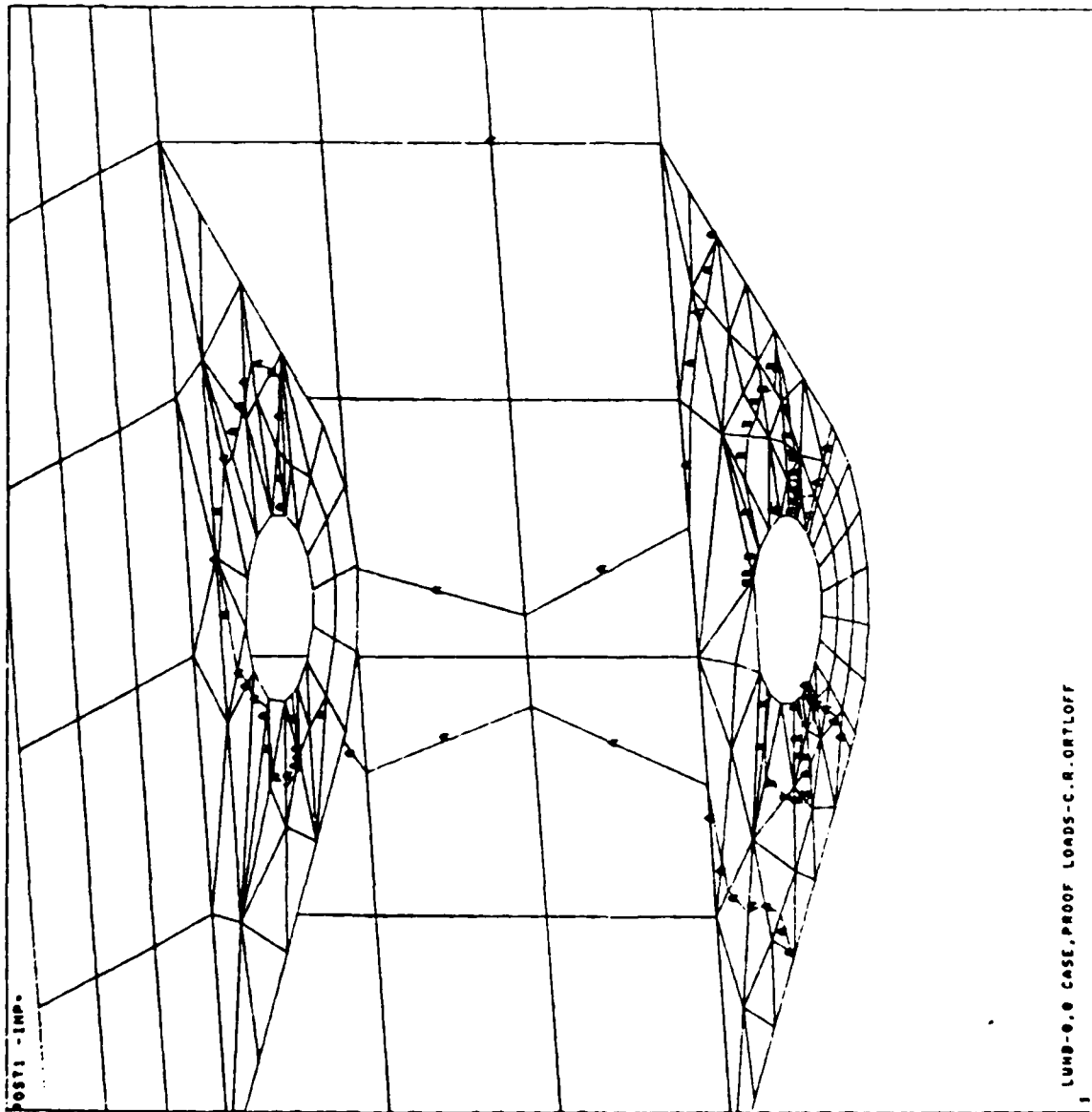
ANSYS 4.20
 DEC 5 1986
 15:04:54
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.420
 SICE
 TOP
 ZOOM
 XU=-1
 YU=-1
 ZU=-1
 DIST=52.0
 WF=54.1
 VF=-2.93
 ZF=4.93
 VRT0=1.65
 MIDDEN
 RA=22061
 RH=101
 A=3827
 B=7474
 C=11121
 D=14768
 E=18415



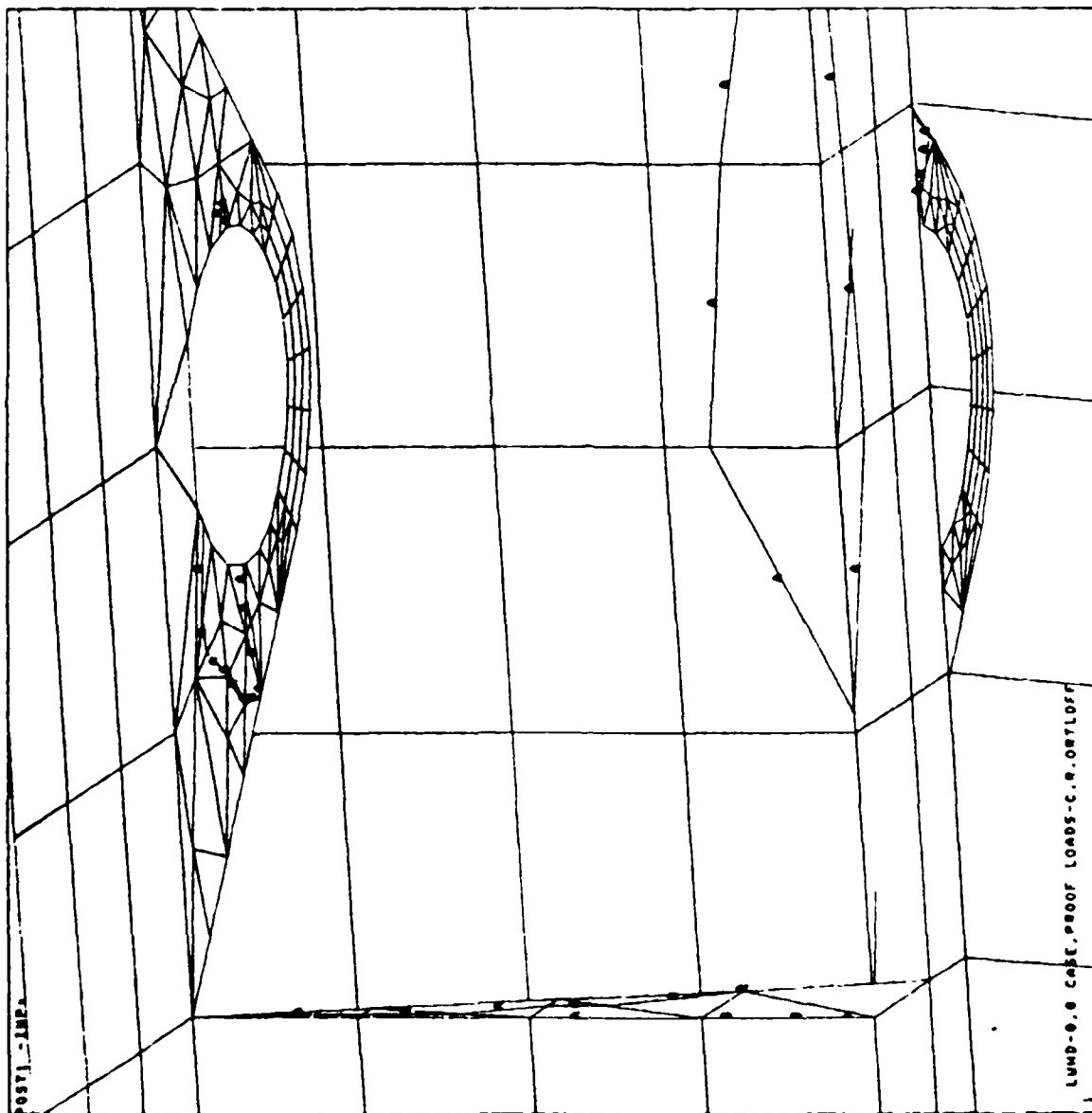
ANSYS 4.23
 DEC 8 1986
 10:49:36
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.013
 SICE
 TOP
 XU=.2
 YU=.3
 ZU=-1
 DIST=59.3
 XF=62.8
 YF=25.6
 ZF=6.46
 HIDDEN
 NA=159893
 AN=176
 A=26784
 B=53414
 C=80034
 D=106654
 E=133274



ANSYS 4.20
 DEC 8 1986
 10:40:36
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.013
 SICE
 TOP
 ZOOM
 XU=.2
 YU=.3
 ZU=-.1
 DIST=0
 XZ=48.6
 YZ=54.2
 ZF=14.2
 VRT0=1.28
 WIDDEM
 MM=82893
 MM=0
 A=26784
 B=53414
 C=88034



ANSYS 4.20
 DEC 8 1986
 11:01:00
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.013
 SLOE
 TOP
 ZOOM
 XU=.2
 VU=.3
 ZU=-1
 B DIST=8.61
 B KF=54.5
 B VF=3.62
 B ZF=.17
 XRTD=1.19
 VRTD=1.28
 MIDDLE
 RK=124272
 RM=0
 A=26794
 B=53414
 C=80034
 D=106654

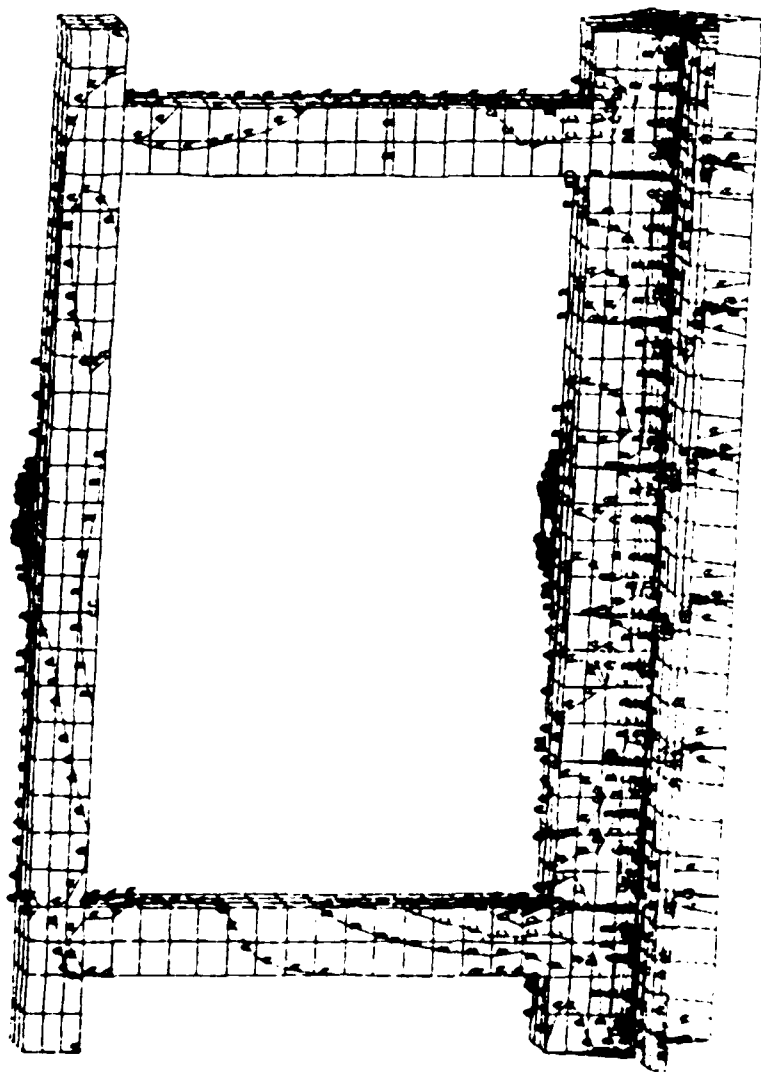


243

PLATFORM
 BOTTOM

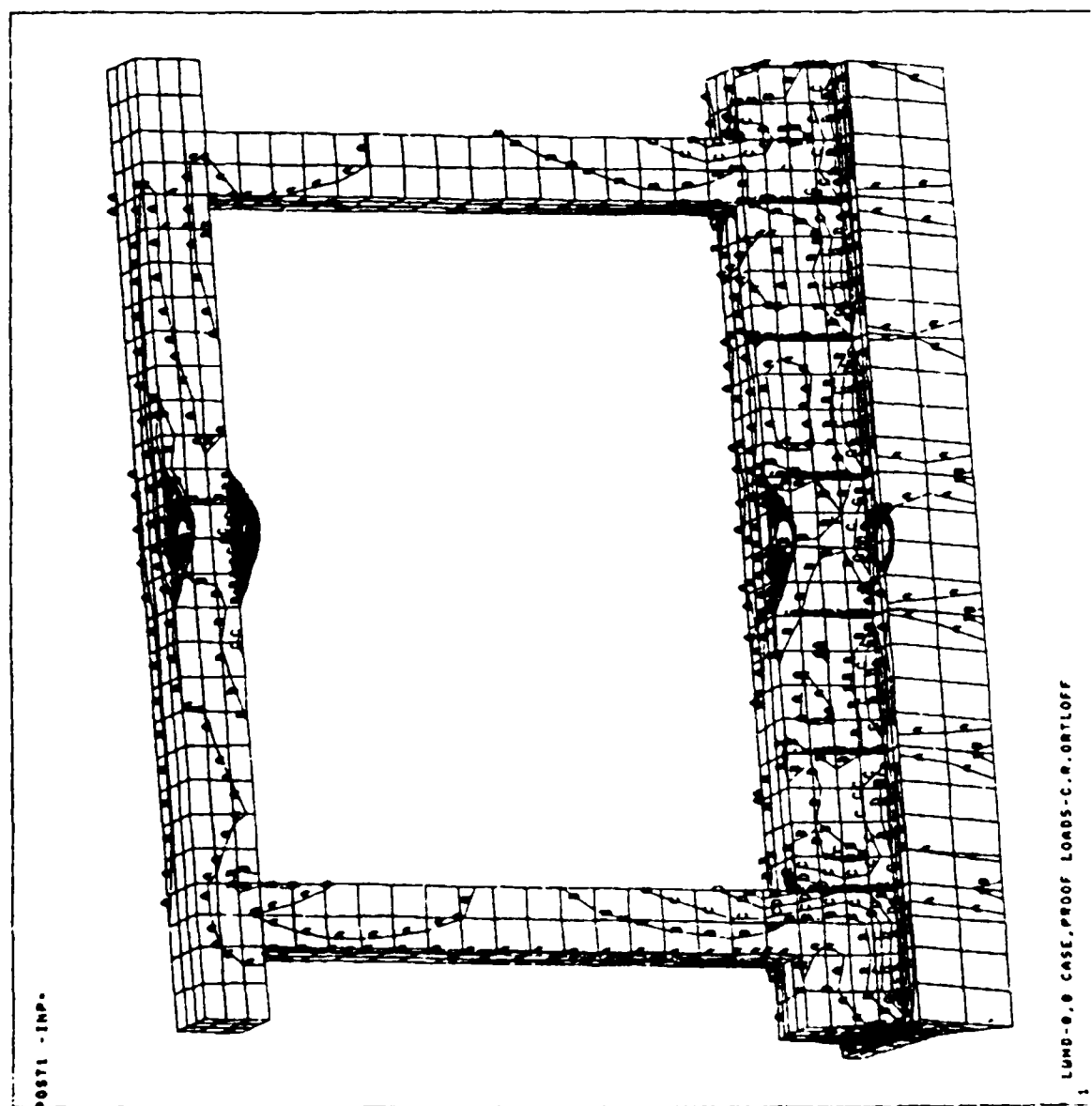
ANSYS 4.28
 DEC 8 1986
 11:14:33
 POST1 STRESS
 STEP=1
 ITEM=1
 TIME=.013
 SICE
 TOP
 XU=.2
 YU=.3
 ZU=.1
 DIST=59.3
 XF=52.4
 YF=27.3
 ZF=2.89
 MIDDEN
 RM=150893
 RM=176
 A=10153
 B=20136
 C=30119
 D=40102
 E=50085
 F=60068
 G=70051
 H=80034
 I=90017
 J=100000
 K=109983
 L=119966
 M=129949
 N=139932
 O=149915

POST1 -IMP.

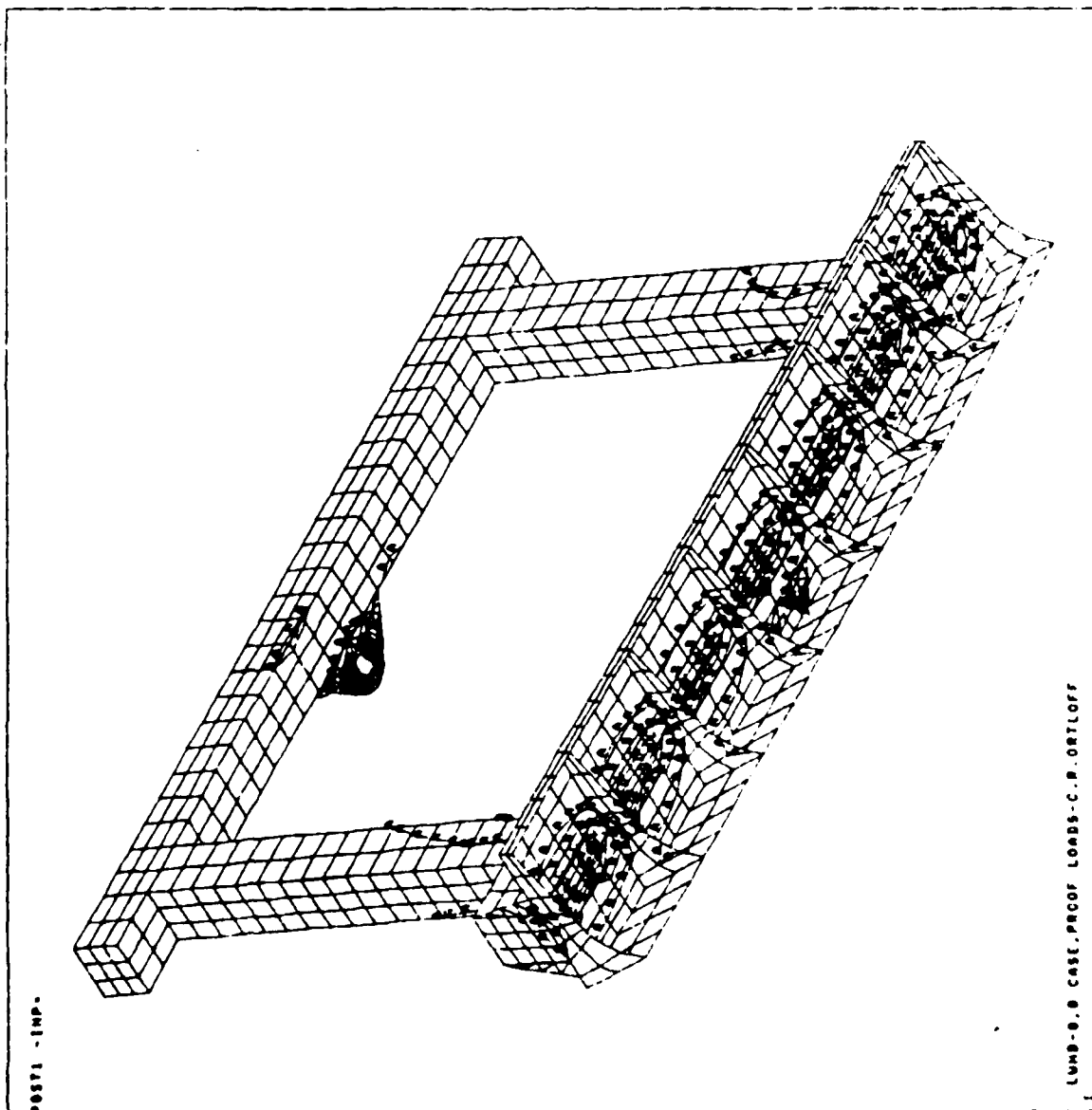


LUMP=0.0 CASE,PROOF LOMES-C.B.ORTLCFF

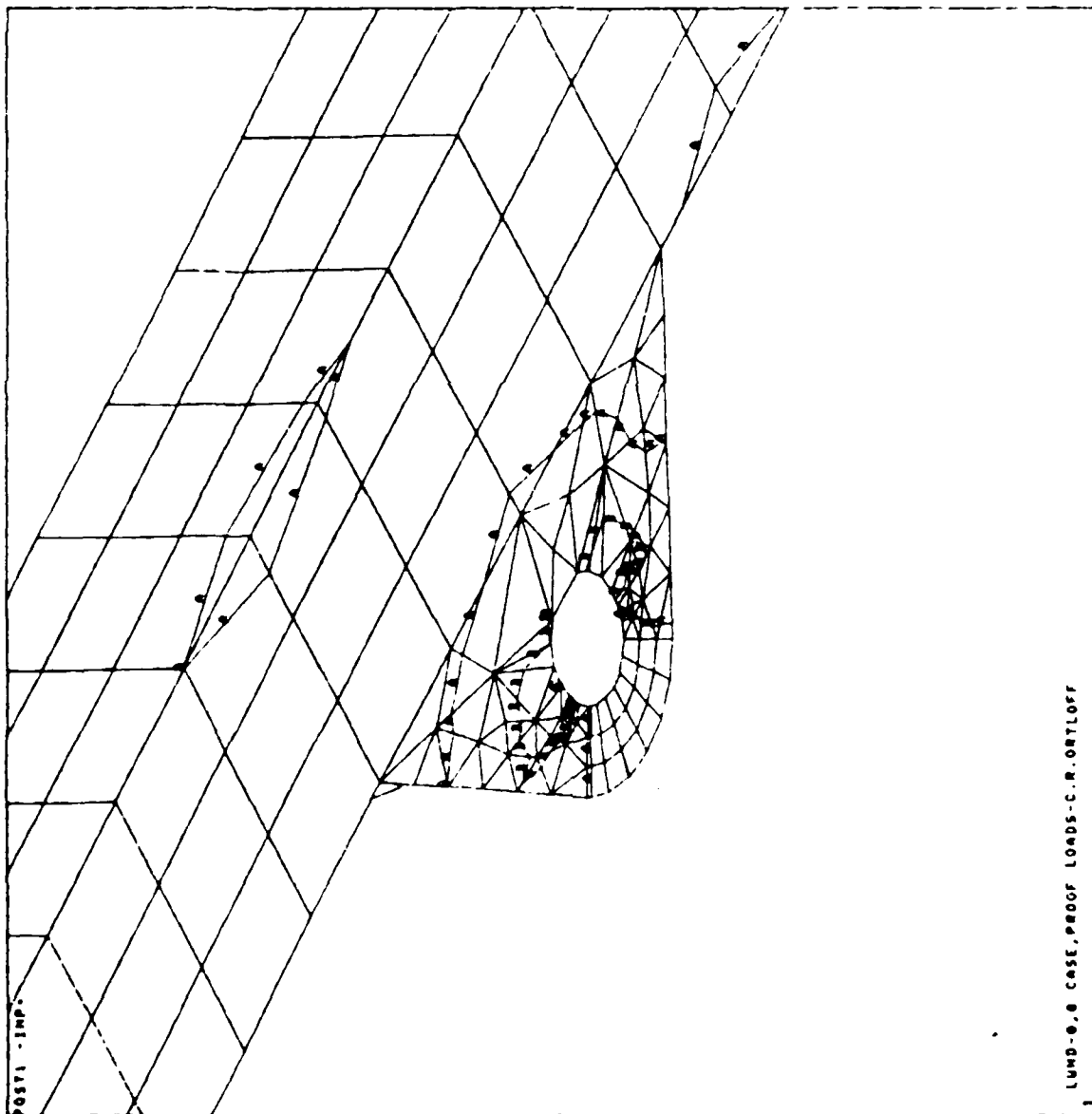
ANSYS 4.2D
 DEC 8 1988
 11:01:09
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.013
 SICE
 TOP
 ZOOM
 XU=.2
 YU=.3
 VU=-1
 DIST=59.3
 MF=82.8
 VF=25.6
 ZF=6.46
 VRTD=1.28
 WIDEN
 MX=158803
 MY=176
 A=10153
 B=20136
 C=30119
 D=40102
 E=50085
 F=60068
 G=70051
 H=80034
 I=90017
 J=100000
 K=109983
 L=119966
 M=129949
 N=139932
 O=149915



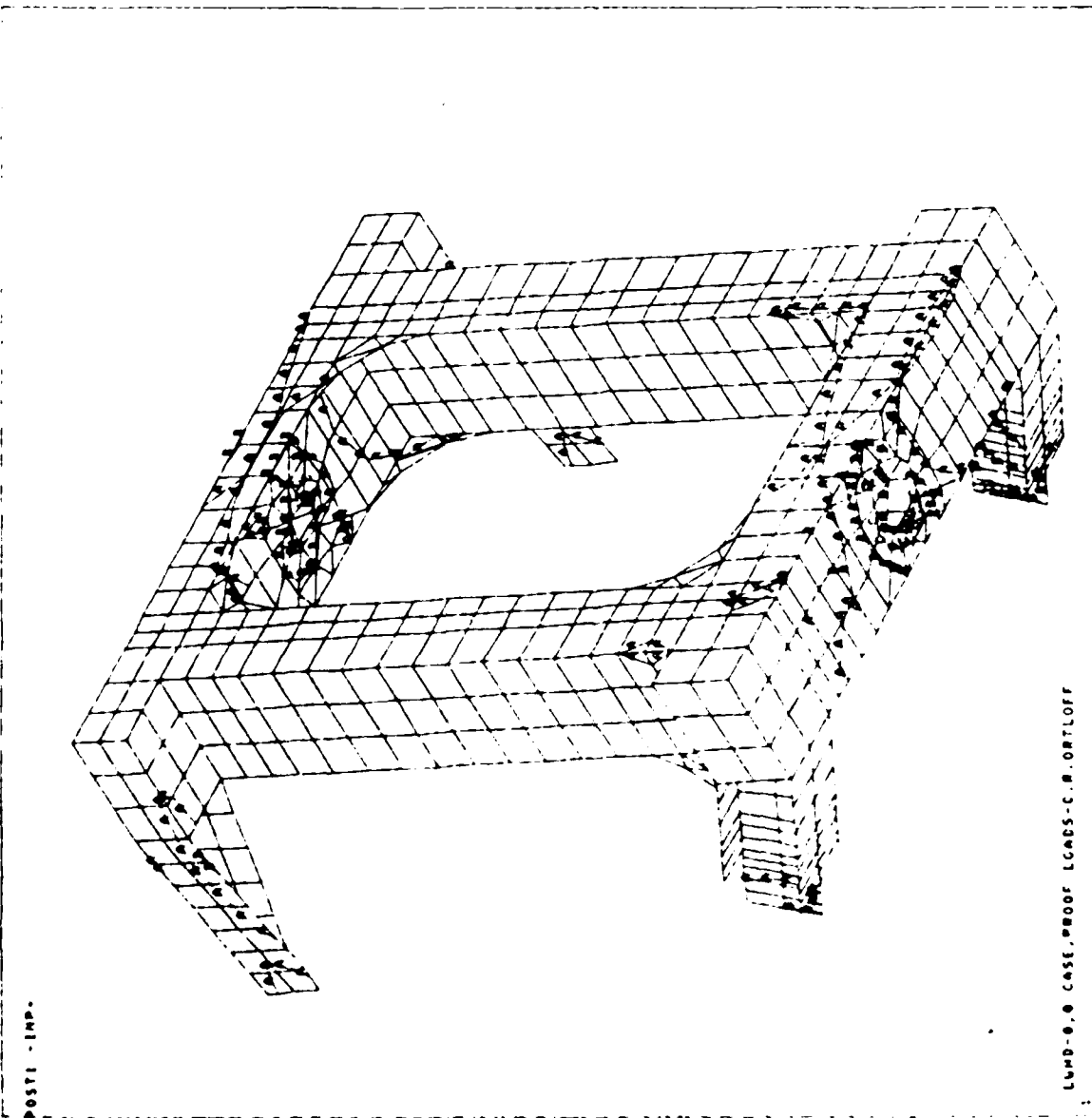
ANALYS 4.00
 DEC 8 1986
 10:37:10
 POST1 STRESS
 STEP=1
 ITEM=1
 TIME=.013
 SICE
 TOP
 XU=-1
 YU=-1
 ZU=-1
 DIST=58.2
 XF=54.2
 YF=26.4
 ZF=4.86
 HIDDEN
 RH=158893
 RM=176
 A=26794
 B=53414
 C=80034
 D=106654
 E=133274

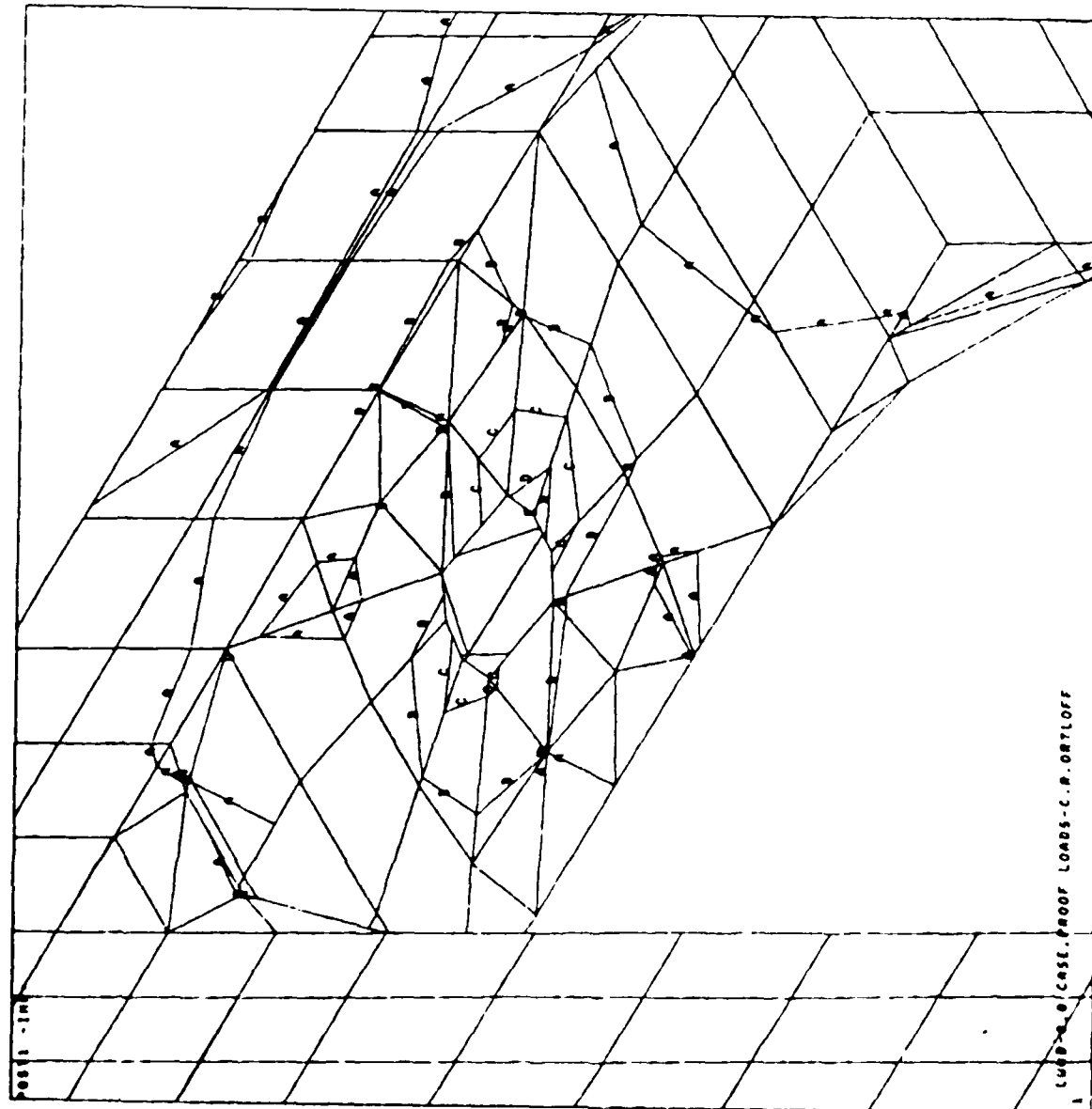


ANSYS 4.20
 DEC 8 1986
 10:33:19
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.013
 SICE
 TOP
 ZOOM
 XU=-1
 YU=-1
 VU=-1
 ZU=-1
 DIST=12.3
 ZF=49.8
 VF=44.7
 ZF=9.77
 XRAY=1.11
 HIDDEN
 HA=82893
 HA=0
 A=26784
 B=53414
 C=88034



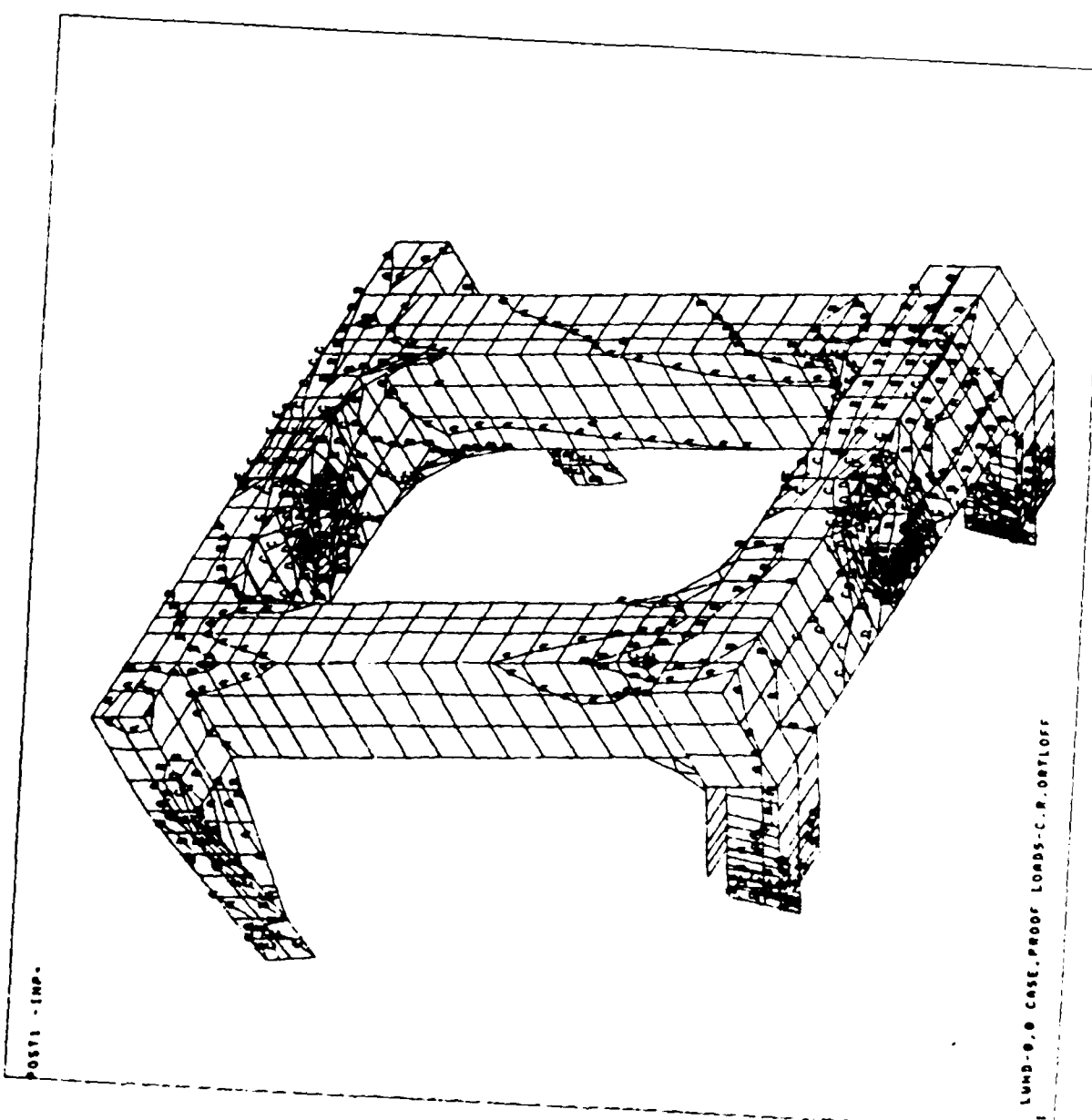
ANSYS 4.28
 BEC 8 1986
 11-27-86
 POST1 STRESS
 STEP=1
 TIME=1
 TIME=.013
 SLOC
 TOP
 KU=-1
 VU=-1
 ZU=1
 DIST=32.7
 KF=51.6
 VF=35.2
 ZF=8.57
 MIDDLEM
 RM=118834
 RM=1361
 A=20940
 B=40519
 C=64008
 D=79677
 E=99256





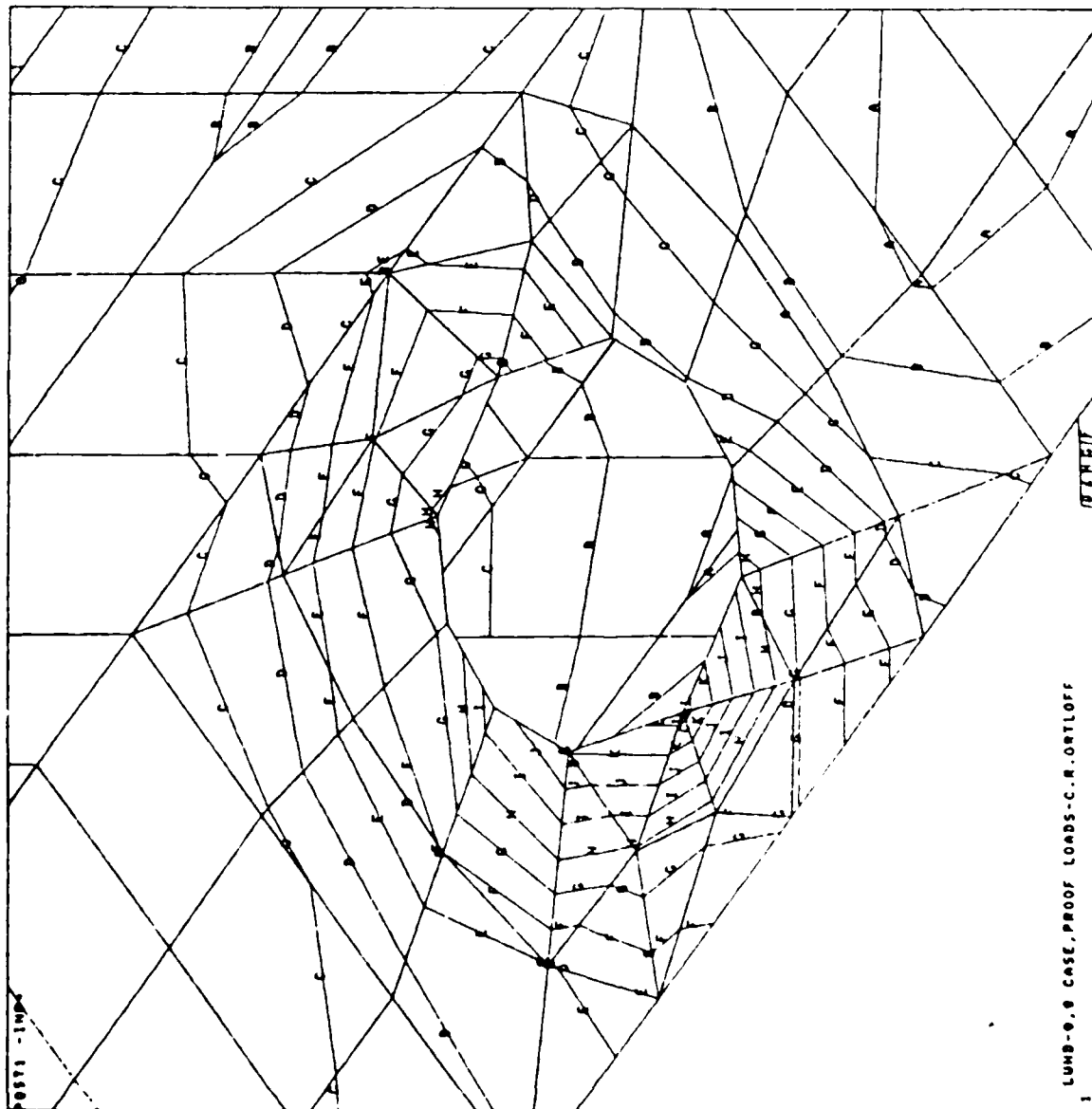
ANSYS 4.20
 DEC 8 1986
 11:27:36
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.013
 SIZE
 TOP
 ZOOM
 XU=-1
 YU=-1
 ZU=1
 DIST=8.14
 WF=48.8
 VF=47.2
 ZF=.527
 VRTD=1.03
 HIDDEN
 PK=103282
 MN=0
 A=20040
 B=40519
 C=60098
 D=79677
 E=90256

TOP

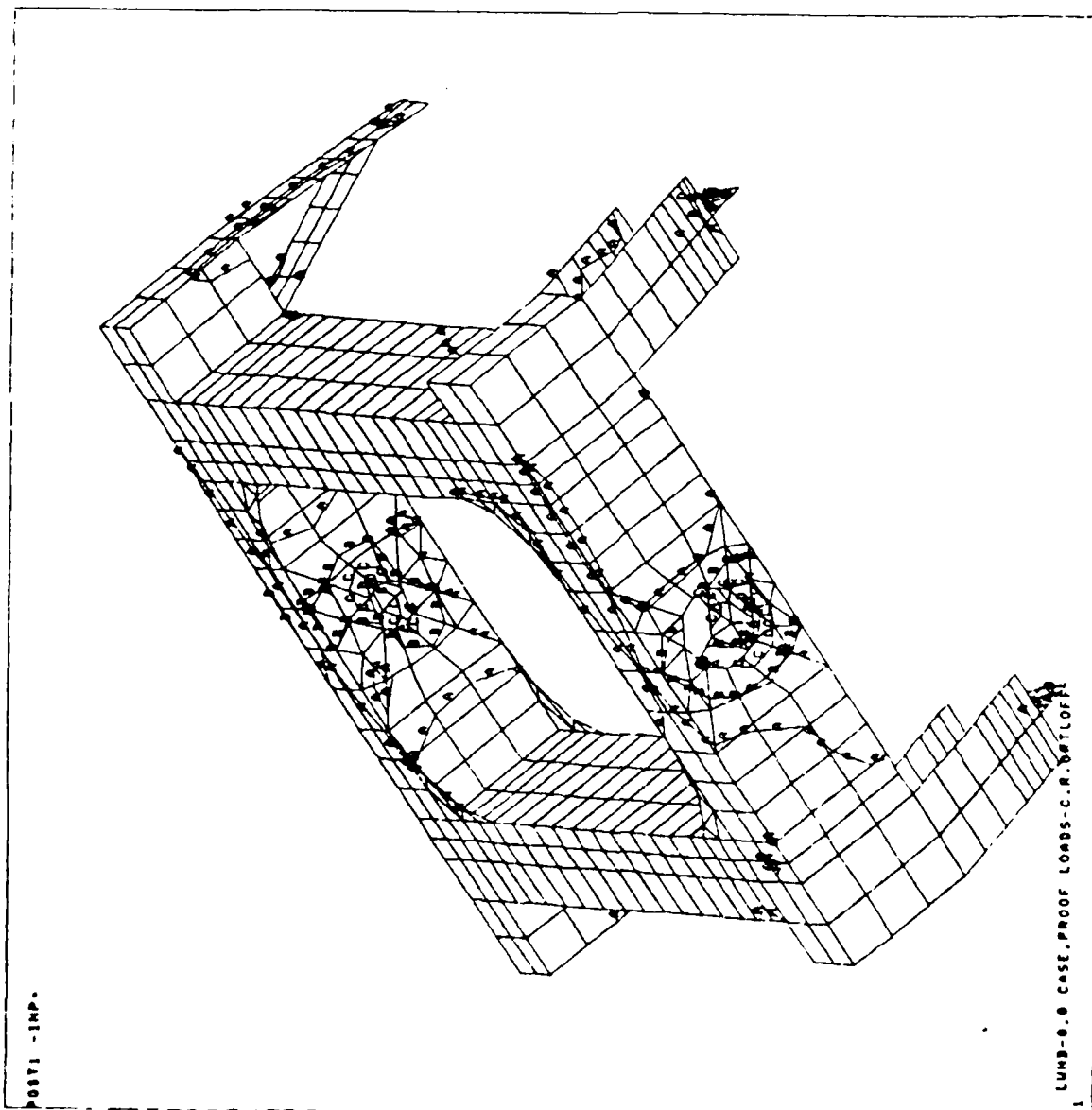


ANSYS 4.20
 DEC 8 1988
 11:38:21
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.013
 SICE
 TOP
 ZOOM
 XU=-1
 YU=-1
 ZU=-1
 DISP=33.7
 XF=51.6
 YF=35.2
 ZF=-8.57
 VRT0=1.03
 HIDDEN
 MX=118834
 MY=1361
 MZ=8697
 B=16640
 C=23383
 D=38726
 E=38069
 F=45412
 G=52755
 H=60088
 I=67491
 J=74784
 K=82127
 L=89470
 M=96813
 N=104156
 O=111499

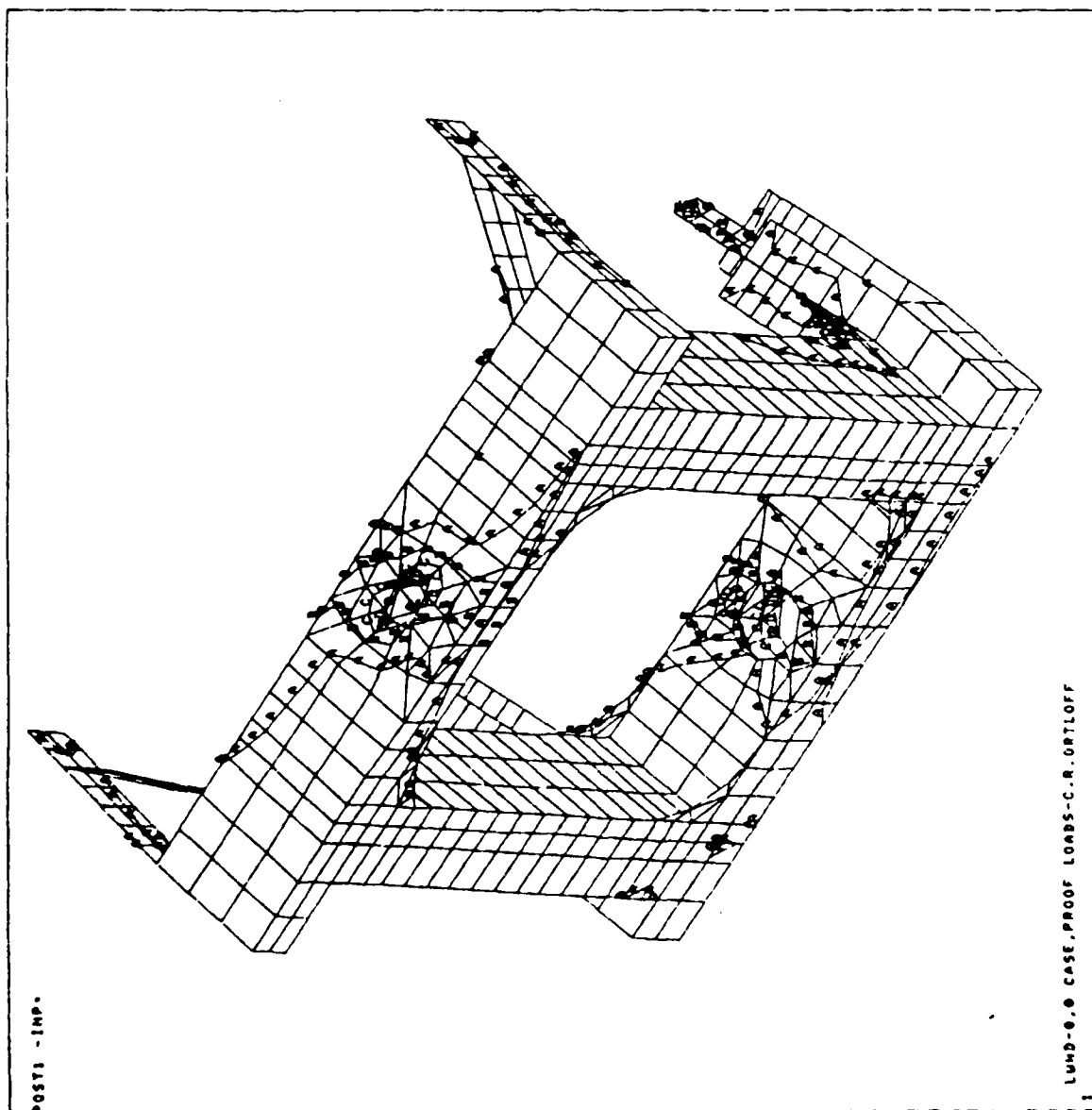
ANSYS 4.20
 DEC 8 1986
 11/36:21
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.013
 SICE
 TOP
 ZOOM
 RV=-1
 VU=-1
 ZU=1
 DIST=5.93
 XF=62.7
 VF=19.2
 ZF=-13.5
 VRT0=1.26
 MIDDEN
 MX=118834
 MY=0
 A=8897
 B=16040
 C=23383
 D=30726
 E=38069
 F=45412
 G=52755
 H=60098
 I=67441
 J=74784
 K=82127
 L=89470
 M=96813
 N=104156
 O=111499



ANSYS 4.28
 DEC 8 1986
 11:46:11
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.013
 SICE
 TOP
 XU=.3
 VU=.1
 ZU=.4
 DIST=30.2
 XF=54.6
 YF=33.1
 ZF=7.74
 MIDDLE
 MN=118834
 MA=1361
 A=20940
 B=40510
 C=60098
 D=79677
 E=98256

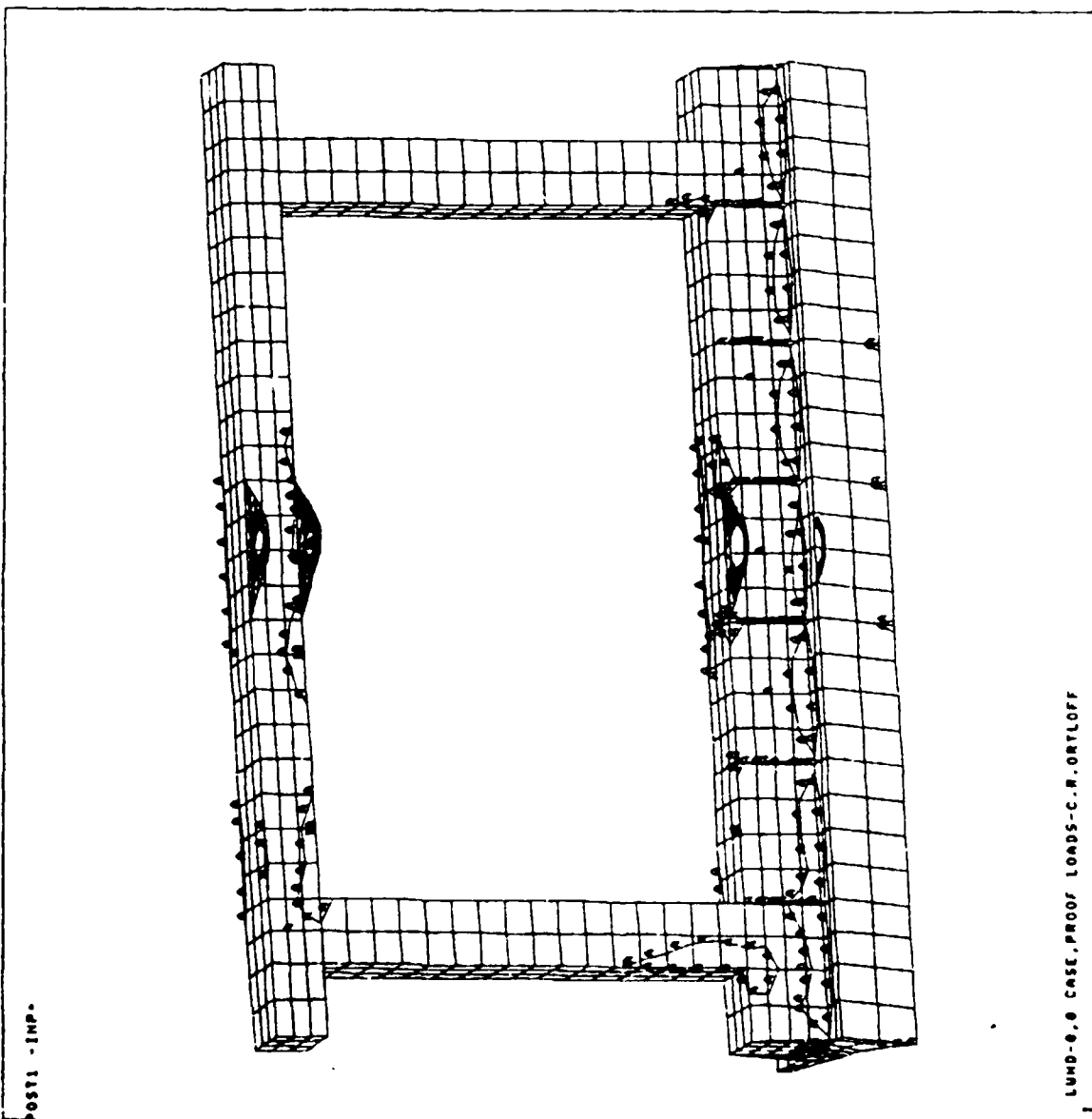


ANSYS 4.2B
 DEC 8 1986
 11:51:47
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.013
 SICE
 TOP
 XU=.3
 YU=1
 ZU=.4
 DIST=31.7
 XF=53.7
 YF=35.2
 ZF=-8.97
 MIDDLEM
 MX=118034
 MY=1361
 A=20940
 B=40510
 C=60000
 D=79677
 E=99256



ANSYS 4.2B
 DEC 8 1986
 13157122
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.28
 SICE
 TOP

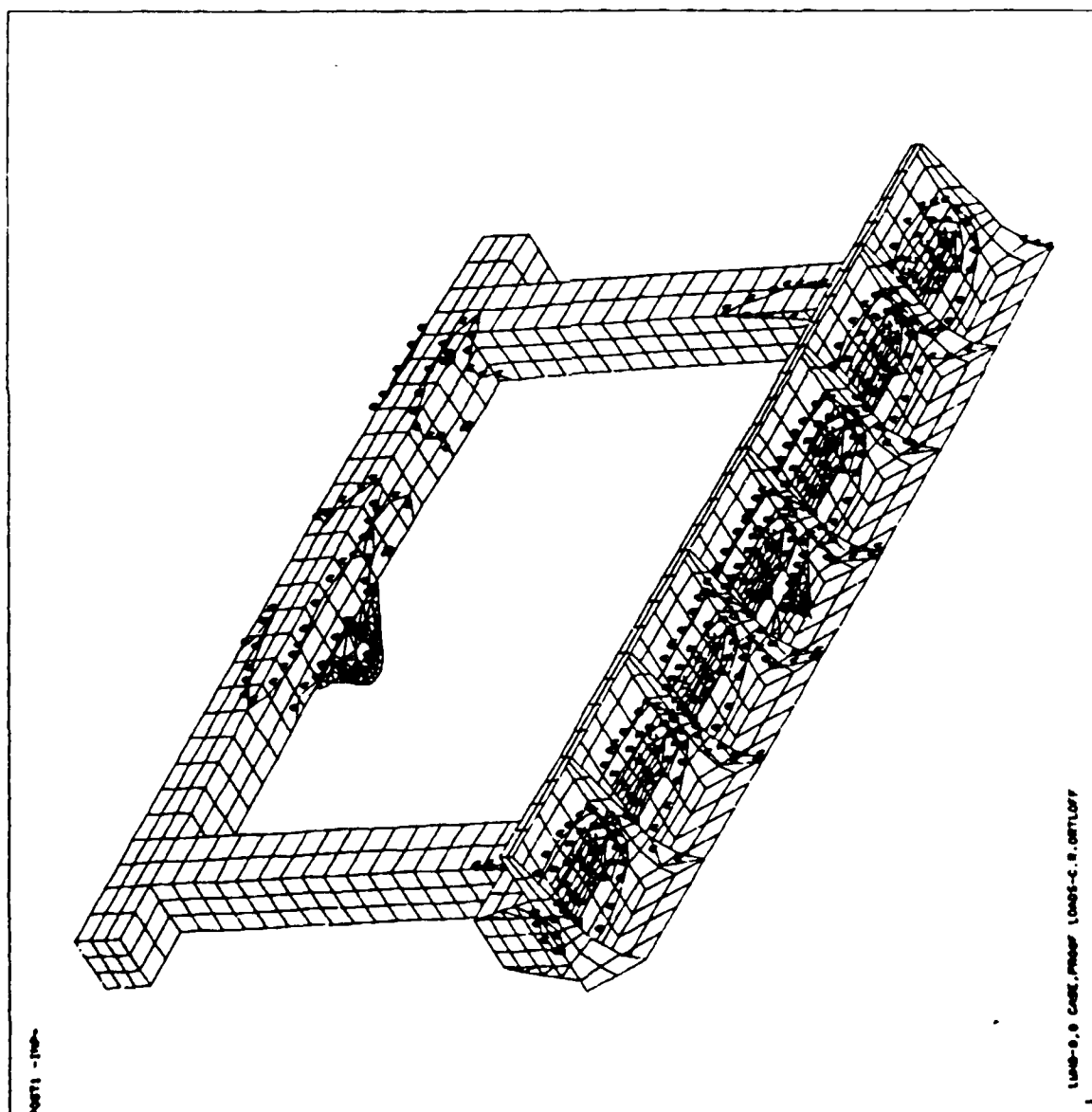
XU=.2
 VU=.3
 ZU=.1
 DIST=59.3
 XF=52.9
 YF=25.6
 ZF=6.48
 MIDDEN
 RK=67714
 RM=248
 A=11491
 B=22736
 C=33981
 D=45226
 E=56471

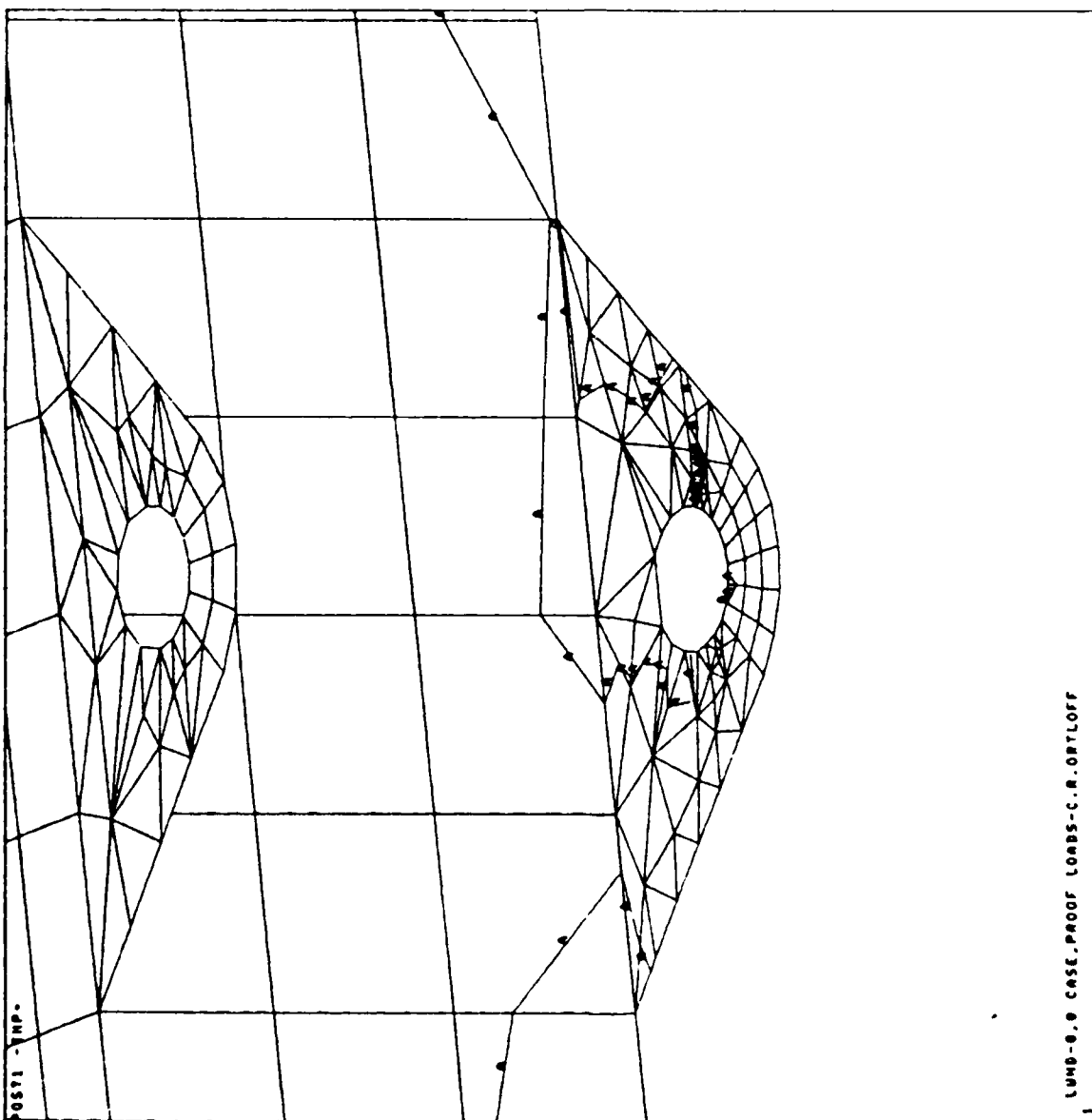


POST1 -IMP.

1 LUMD=0.0 CASE,PROOF LOADS-C.R.ORTLOFF

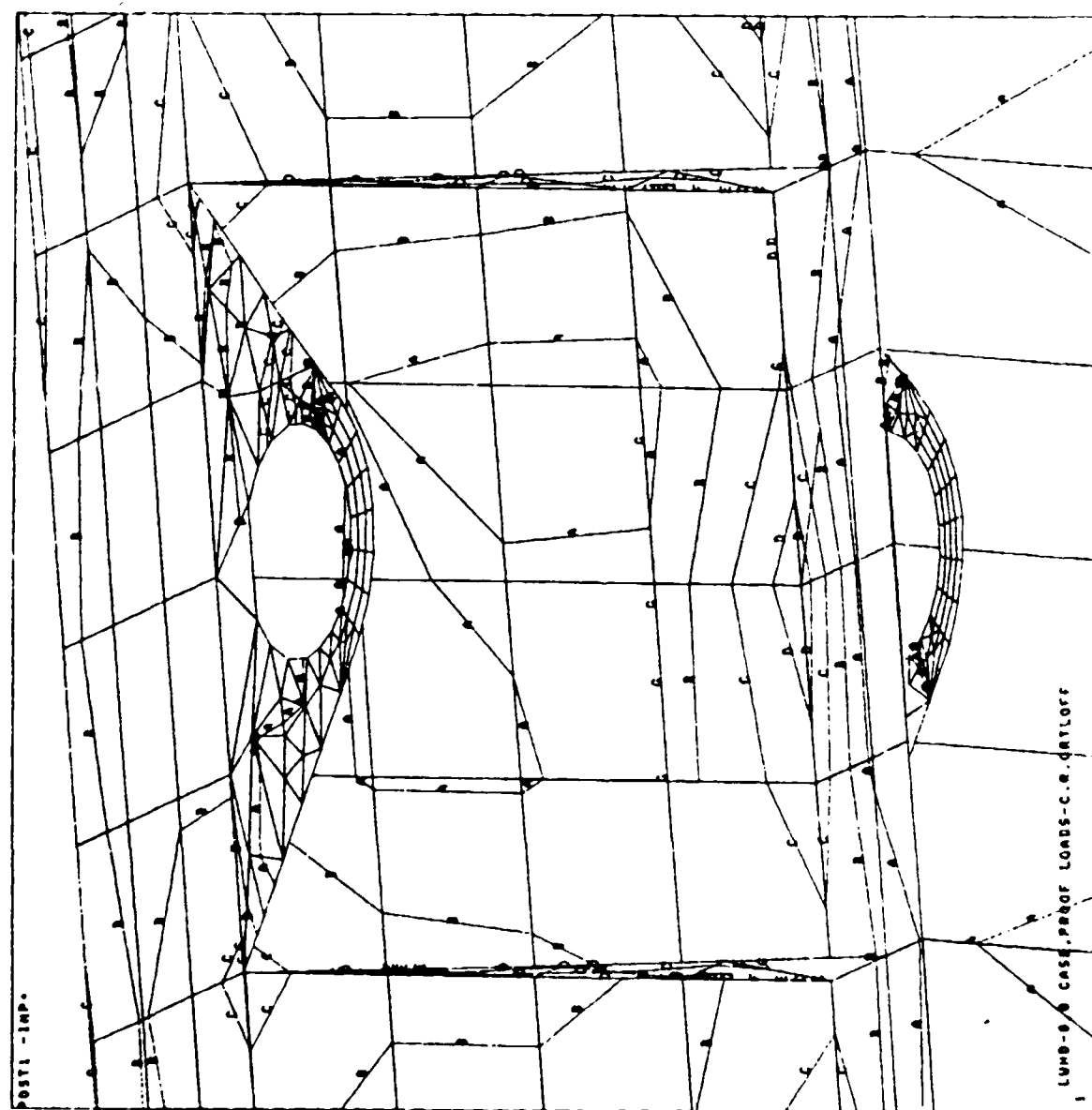
000015 4.20
 DEC 8 1986
 13:48:06
 POST1: STRESS
 STEP=1
 ITER=1
 TIME=.20
 SLOPE
 TOP
 AU=1
 WU=1
 DU=1
 DIST=88.8
 XF=64.2
 YF=88.4
 ZF=4.85
 MI=6771.6
 MM=248
 0=11.081
 8=22728
 C=33081
 D=43226
 E=56471





ANSYS 4.28
 DEC 8 1986
 13:57:22
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.28
 SICE
 TOP
 ZOOM
 XZ=.2
 YZ=.3
 ZU=-1
 DIST=10.4
 XP=49.2
 YF=83.1
 ZF=14
 VRT0=1.78
 HIDDEN
 MX=24645
 MY=0
 A=11491
 B=22736

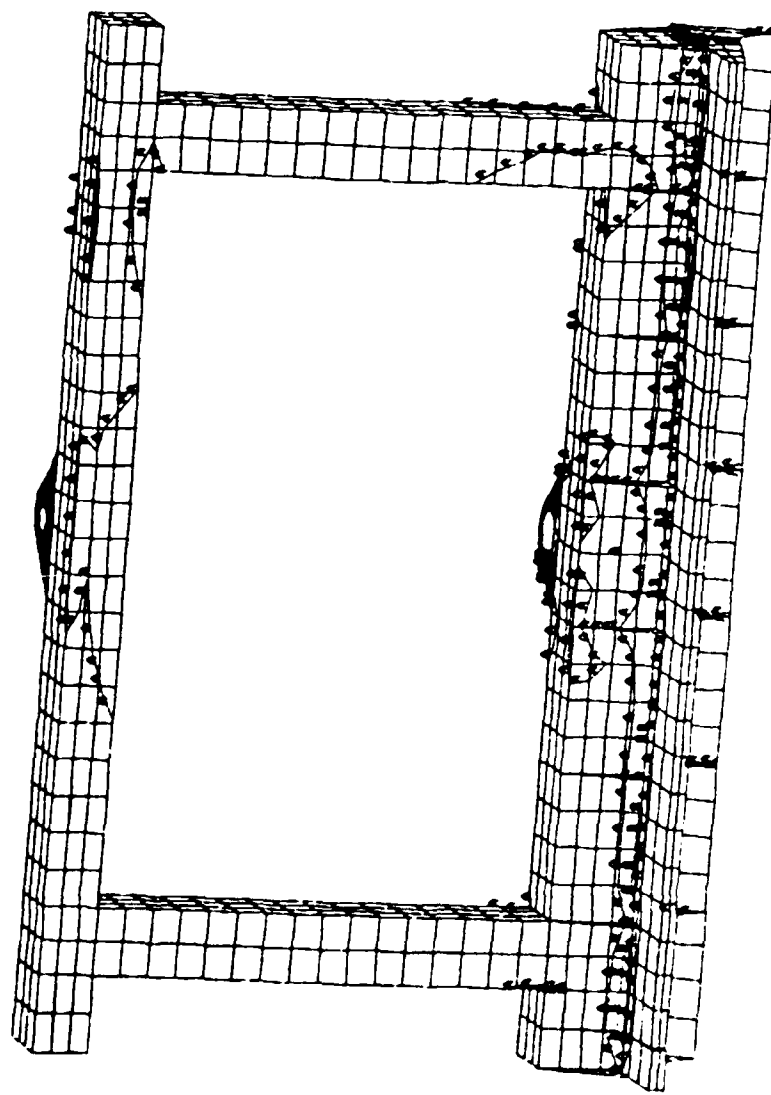
ANSYS 4.20
 DEC 8 1986
 14113101
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.28
 SLOC
 TOP
 ZOOM
 KU=.2
 VU=.3
 ZU=.1
 1 DIST=13.6
 2 XF=52.6
 3 VF=3.5
 4 ZF=-.25
 XRT0=1.31
 VRT0=1.78
 MIDDLE
 MX=57120
 MN=0
 A=4462
 B=8679
 C=12896
 D=17113
 E=21330
 F=25547
 G=29764
 H=33981
 I=38198
 J=42415
 K=46632
 L=50849
 M=55066



257

PLATFORM
 BOTTOM

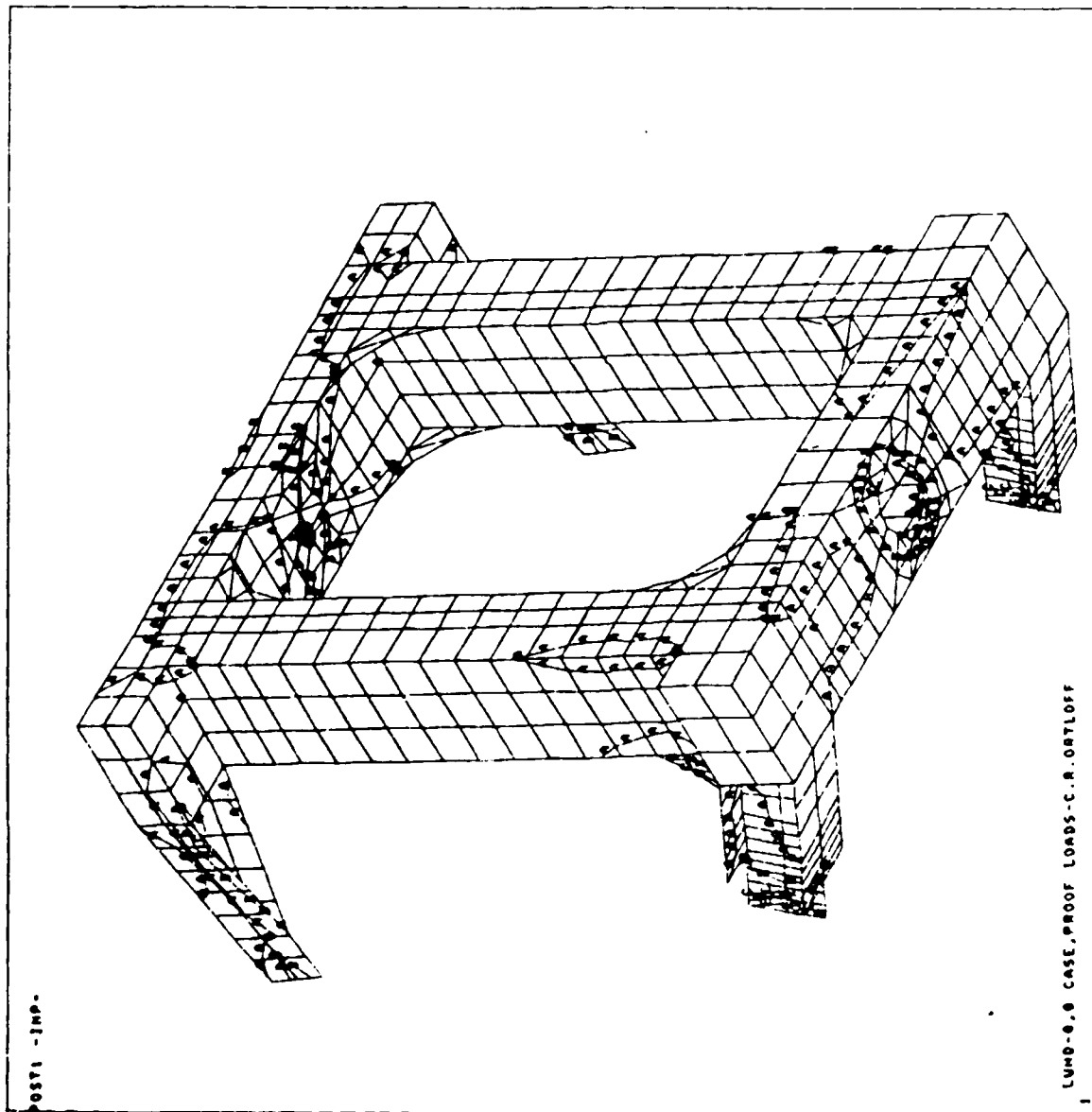
POSTIVE STRESS
POSTIVE -IMP.



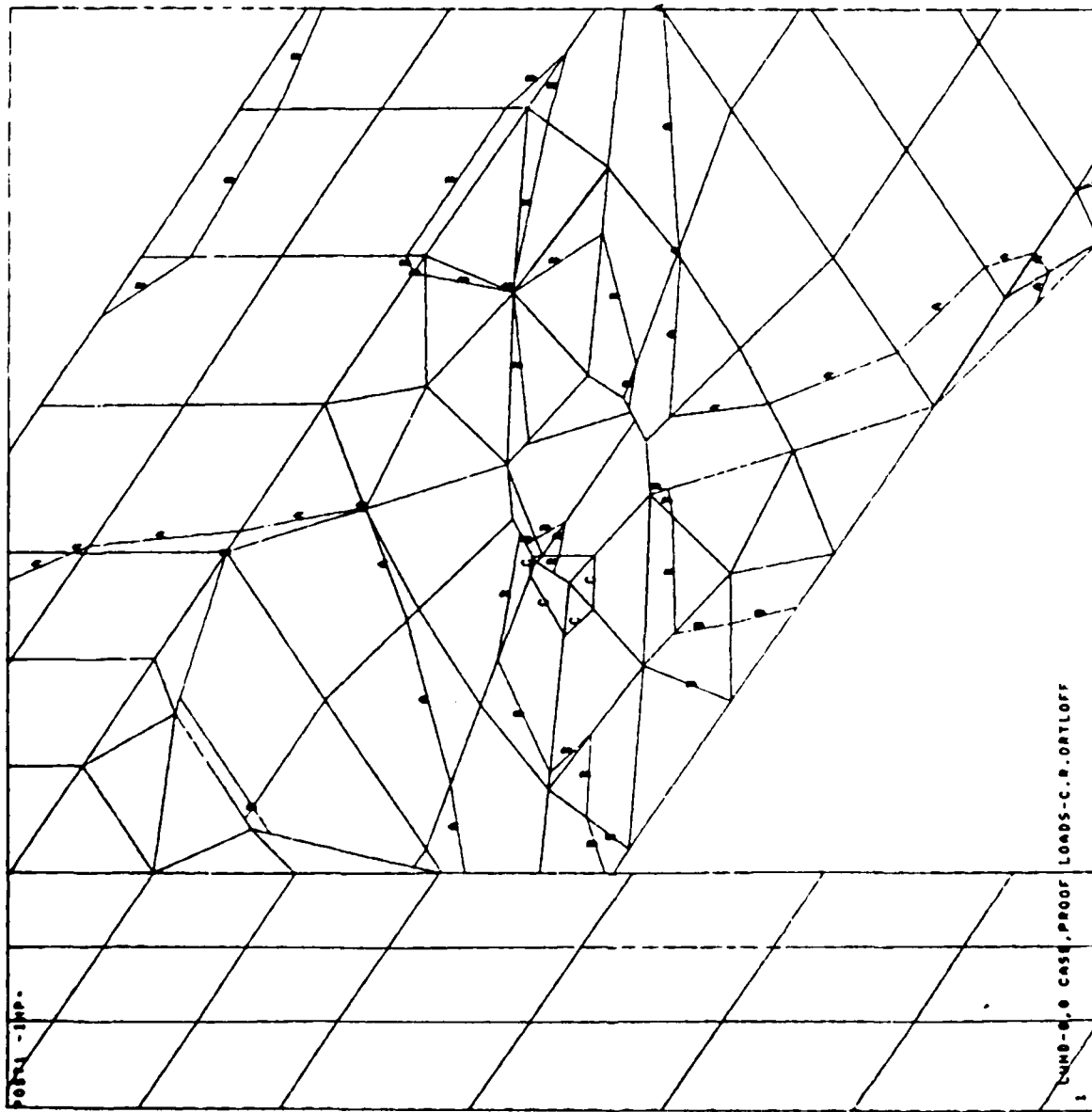
LUND-0.0 CASE, PROOF LOADS-C.R.ORTLOFF

STEP-1
ITER-1
TIME-.28
SLICE
TOP
XU-.2
VU-.4
ZU-1
DIST-59.3
XF-58.4
VF-27.7
ZF-3.15
HIDDEN
MX-67714
MY-248
A-11491
B-22736
C-33981
D-45226
E-56471

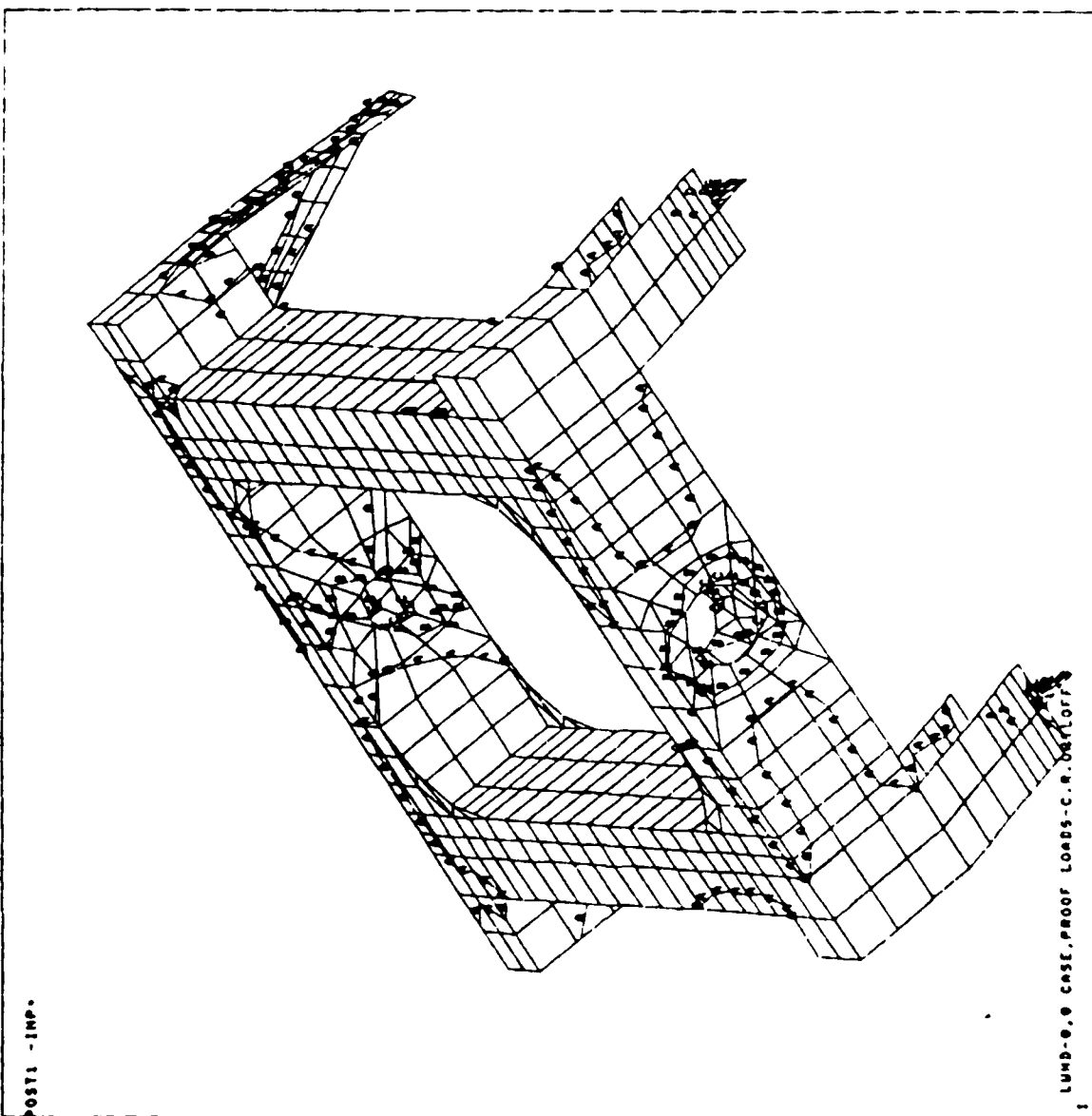
ANSYS 4.28
 DEC 8 1986
 14:38:50
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.28
 SICE
 TOP
 RV=-1
 VU=-1
 ZU=1
 DIST=22.7
 RF=51.6
 VF=35.2
 ZF=-8.57
 MIDDEN
 MX=66819
 MY=523
 MZ=11588
 D=22655
 C=33721
 D=44787
 E=55853



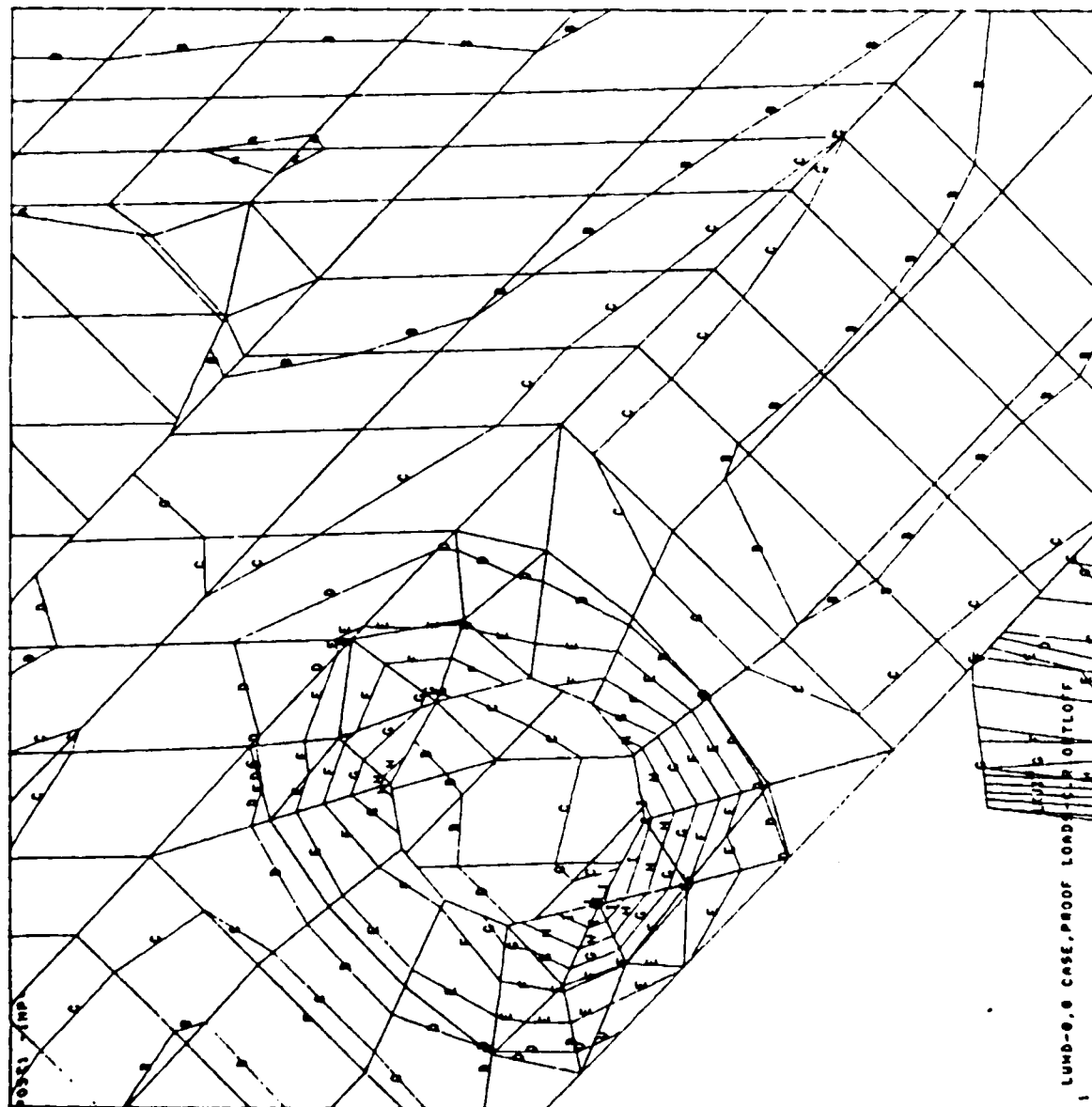
ANSYS 4.20
 DEC 8 1986
 14138159
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.28
 SICE
 TOP
 ZOOM
 KU=1
 VU=1
 ZU=1
 8 DIST=7.82
 8 XF=47.4
 8 VF=48.2
 8 ZF=117
 VRTD=1.18
 HIDDEN
 RM=38080
 RM=0
 A=11589
 B=22655
 C=33721



ANSYS 4.20
 DEC 8 1986
 14147120
 POST1, STRESS
 STEP=1
 TIME=1
 TIME=1.28
 SIZE
 TOP
 XU=.3
 YU=-1
 ZU=.4
 DIST=30.2
 XF=54.6
 YF=33.1
 ZF=7.74
 MIDDLE
 RM=66010
 RM=523
 A=11509
 B=22655
 C=33721
 D=44787
 E=55853



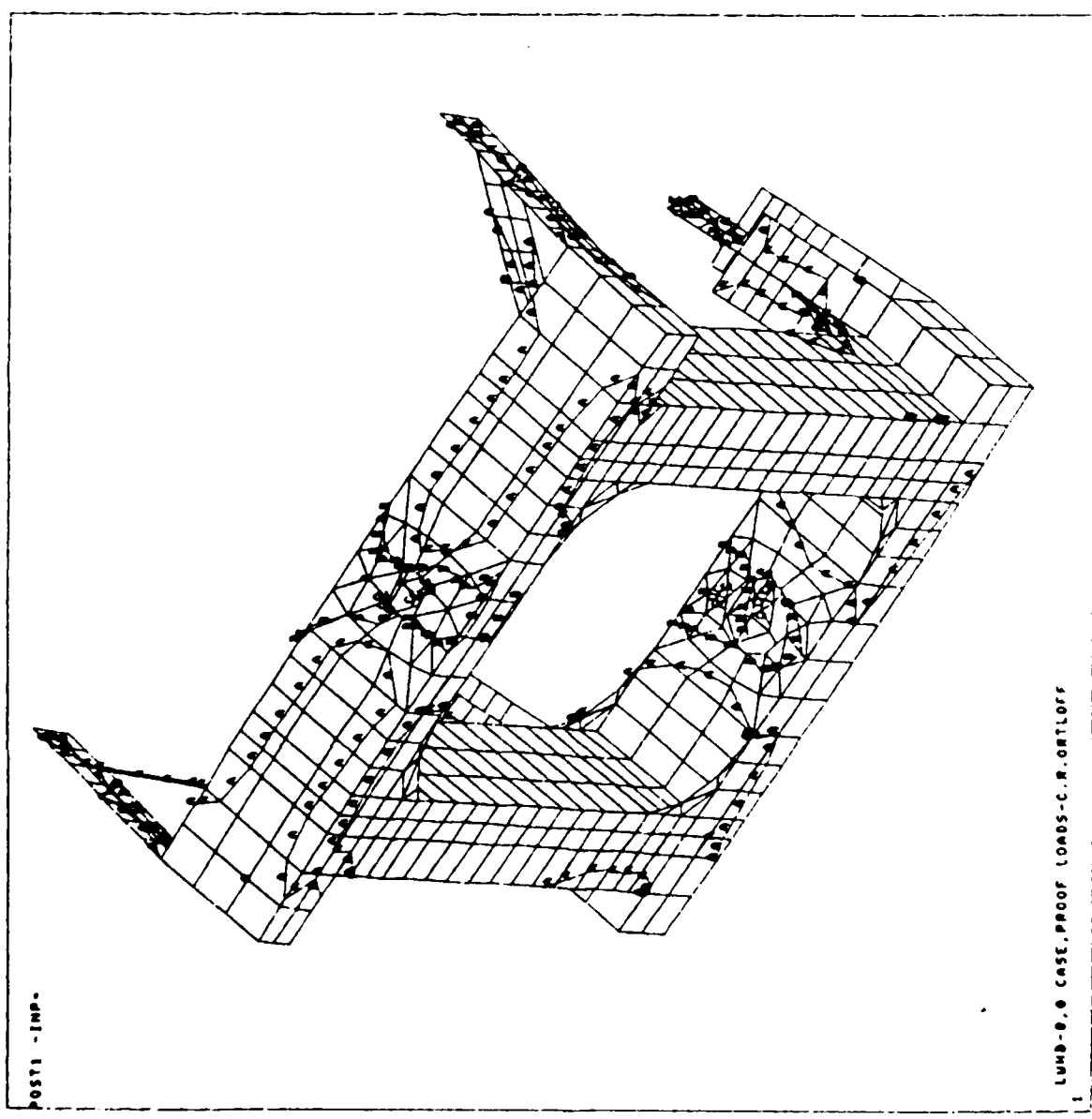
ANSYS 4.20
 DEC 8 1986
 14143140
 POST1 STRESS
 STEP=1
 ITER=1
 VIME=.28
 SLOC
 TOP
 ZOOM
 KU=-1
 VU=-1
 ZU=1
 DIST=9.88
 XF=65.9
 VF=18.1
 ZF=11.3
 VRT0=1.64
 MIDDLE
 MK=57721
 MM=6
 A=4671
 B=8821
 C=12971
 D=17121
 E=21271
 F=25421
 G=29571
 H=33721
 I=37871
 J=42021
 K=46171
 L=50321
 M=54471



```

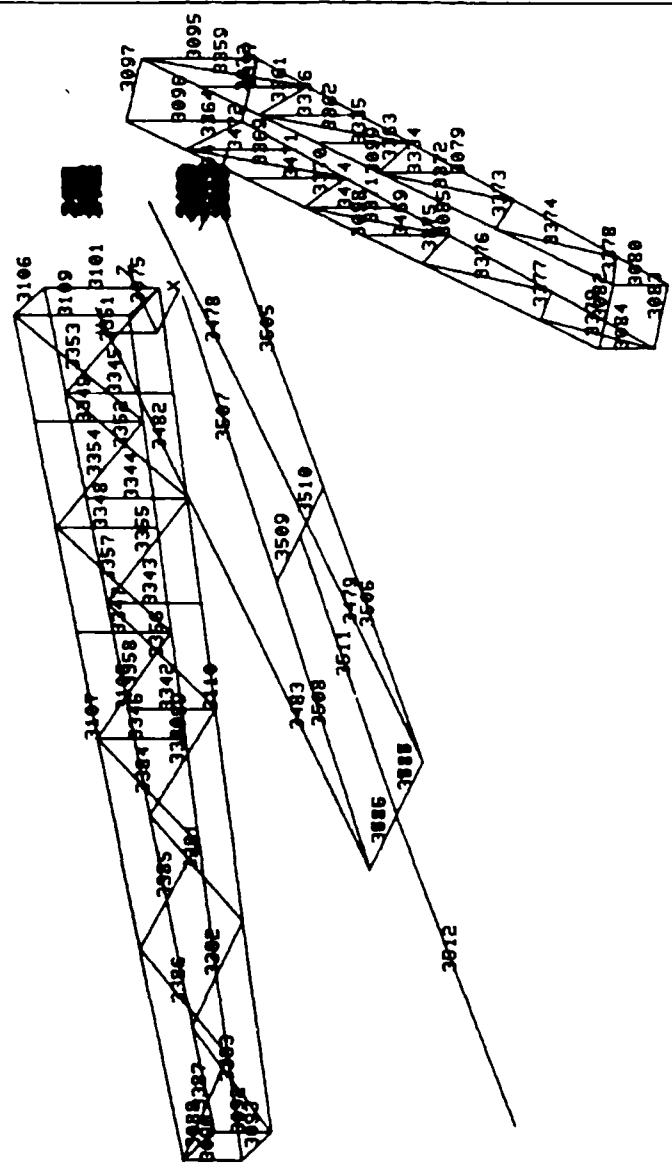
ANSYS 4.20
DEC 8 1986
14:51:34
POST1 STRESS
STEP=1
ITER=1
TIME=.28
SIZE
TOP
XU=.3
YU=.1
ZU=.4
DIST=31.7
XF=53.7
YF=35.2
ZF=-8.97
HIDDEN
MM=66910
NN=523
A=11589
B=22655
C=33721
D=44787
E=55853

```



ANSYS 4.82
 DEC 9 1986
 13:08:02
 PREP7 ELEMENTS
 ENUM=1
 XU=-1
 YU=-1
 ZU=1
 DIST=241
 XF=51.9
 YF=31.8
 ZF=-166
 KRT0=1.37
 VRT0=1.17

PREP7 -IMP.
 ELIST,3478
 LIST SELECTED ELEM. IN RANGE 3478 TO 3478 BY 1 (LIST NODES)
 ELEM MAT TYP REL
 3478 37 7 37 2813 2963 0
 PREP7 -IMP.



1 LUND-9.0 CASE, PROOF LOADS-C.R.ORTLOFF

t = 0.18 sec

PRINFOR

PRINT REACTION FORCES PER NODE

***** POST1 REACTION FORCE LISTING *****

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.28000 LOAD CASE= 1

THE FOLLOWING X,Y,Z FORCES ARE IN MODAL COORDINATES

| MODE | FX | FY | FZ | MX | MY | MZ |
|------|--------|----|----|----|----|----|
| 856 | -2950. | | | | | |
| 857 | -6749. | | | | | |
| 858 | -7033. | | | | | |
| 859 | -5772. | | | | | |
| 860 | -2501. | | | | | |
| 861 | -6371. | | | | | |
| 862 | -6323. | | | | | |
| 863 | -2468. | | | | | |
| 864 | -6265. | | | | | |
| 865 | -6266. | | | | | |
| 866 | -3279. | | | | | |
| 867 | -6992. | | | | | |

MORE (YES, NO OR CONTINUOUS) *

***** POST1 REACTION FORCE LISTING *****

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.28000 LOAD CASE= 1

THE FOLLOWING X,Y,Z FORCES ARE IN MODAL COORDINATES

| MODE | FX | FY | FZ | MX | MY | MZ |
|------|--------|-------|--------|----|----|----|
| 891 | -6481. | | | | | |
| 892 | -2636. | | | | | |
| 893 | -6031. | | | | | |
| 894 | -7232. | | | | | |
| 895 | -3038. | | | | | |
| 896 | -7087. | | | | | |
| 897 | -3081. | | | | | |
| 898 | -8030. | | | | | |
| 899 | -6936. | | | | | |
| 900 | 642.6 | 3121. | -822.5 | | | |
| 901 | 1270 | 879.3 | -353.1 | | | |
| 902 | 454.9 | 1714. | -739.7 | | | |

***** POST1 REACTION FORCE LISTING *****

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.28000 LOAD CASE= 1

THE FOLLOWING X,Y,Z FORCES ARE IN MODAL COORDINATES

| MODE | FX | FY | FZ | MX | MY | MZ |
|------|--------|------------|--------|----|----|----|
| 1284 | 775.0 | 0.1278E+05 | 3414. | | | |
| 1285 | 1700. | 1846. | -726.0 | | | |
| 1286 | 345.0 | 0.1428E+05 | 5980. | | | |
| 1287 | -134.0 | 1860. | -718.4 | | | |
| 1288 | 478.6 | 631.3 | -255.4 | | | |
| 1289 | 1007. | 1210. | -461.9 | | | |
| 1290 | 134.4 | 0.1334E+05 | 7613. | | | |
| 1291 | 756.0 | 1058. | -325.1 | | | |

| | | | |
|------|--------|------------|--------|
| 1298 | 123.4 | 80.40 | -41.07 |
| 1299 | 442.9 | 295.4 | -100.9 |
| 1300 | -240.8 | 0.1485E+05 | 7050. |
| 1301 | -184.1 | 331.2 | -93.16 |

***** POST1 REACTION FORCE LISTING *****

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.28000 LOAD CASE= 1

THE FOLLOWING X,Y,Z FORCES ARE IN MODAL COORDINATES

| MODE | FX | FY | FZ | MX | MY | MZ |
|------|--------|------------|--------|----|----|----|
| 1306 | 63.88 | 91.95 | -26.60 | | | |
| 1307 | 357.7 | 929.1 | -339.6 | | | |
| 1308 | -385.3 | 0.1262E+05 | 4658. | | | |
| 1309 | -806.5 | 1086. | -410.2 | | | |
| 1310 | -885.1 | 518.4 | -216.2 | | | |
| 1311 | -265.6 | 1336. | -516.4 | | | |
| 1312 | -678.5 | 0.1179E+05 | 1171. | | | |
| 1313 | -911.8 | 1412. | -542.0 | | | |
| 1314 | -234.5 | 930.2 | -377.0 | | | |
| 1315 | 636.2 | 2513. | -986.6 | | | |
| 1316 | -954.5 | 1366. | -541.2 | | | |
| 1317 | -1841. | 2492. | -990.4 | | | |

***** POST1 REACTION FORCE LISTING *****

LOAD STEP 1 ITERATION= 1 SECTION= 1
TIME= 0.28000 LOAD CASE= 1

THE FOLLOWING X,Y,Z FORCES ARE IN MODAL COORDINATES

| MODE | FX | FY | FZ | MX | MY | MZ |
|-------------|--------|-------|------------|----|----|----|
| 1332 | -707.7 | 9823. | 849.0 | | | |
| 1333 | 233.0 | 3221. | -1338. | | | |
| TOTAL | 1067. | 1907. | 0.1074E+05 | | | |
| 00E+00 | | | 0.0000E+00 | | | |
| POST1 -IMP. | | | 0.0000E+00 | | | |

AD-A183 993

LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR PHASE 1 AND
PARTIAL PHASE 2 VOLUM (U) FNC CORP MINNEAPOLIS MINN
NORTHERN ORDNANCE DIV R RATHE ET AL APR 87

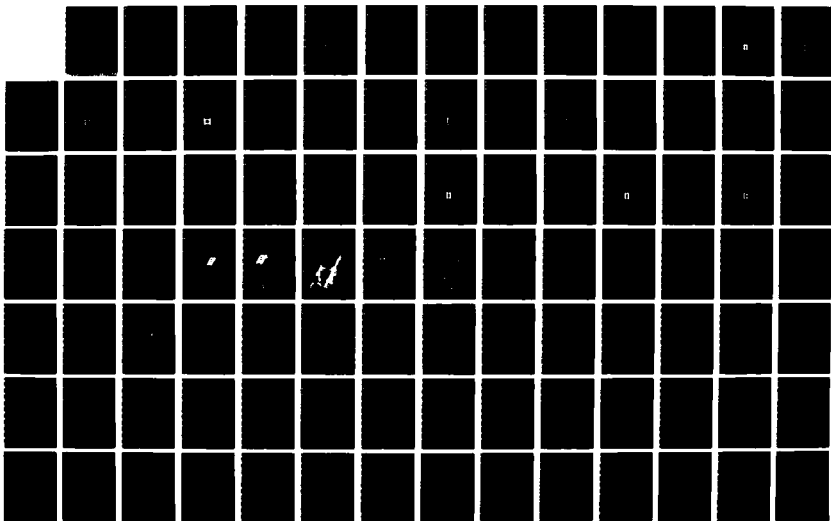
275

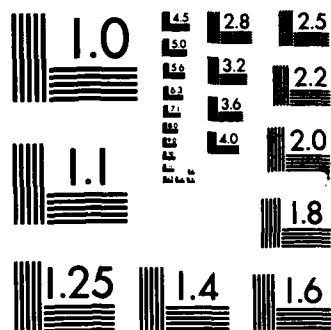
UNCLASSIFIED

FNC-E-3841-VOL-D3-PT-1 DAAA21-86-C-8847

F/G 19/6

NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

$t = 0.20 \text{ sec}$

POINT ELEMENT STRESS ITEMS PER ELEMENT

SESS POST1 ELEMENT STRESS LISTING SESS
TIME: 0.20000

| LOAD STEP | ITERATION | LOAD CASE | SECTION | 1 |
|-----------|-----------|-----------|-----------|---------|
| ELEM | FX | FY | FZ | SDIR |
| 3340 | 179.30 | 17.429 | 47.876 | -433.41 |
| 3341 | -1340.9 | -110.220 | 53.419 | -885.98 |
| 3342 | 300.753 | 110.220 | 53.419 | -885.98 |
| 3343 | 1640.8 | 1.0285 | -0.0311 | -4217.8 |
| 3344 | 318.00 | 318.01 | 3.1007 | 87.132 |
| 3345 | -31.890 | -109.31 | 3.1007 | 87.132 |
| 3346 | 140.97 | 119.293 | 52.304 | 394.65 |
| 3347 | 376.48 | 103.67 | -131.31 | -891.60 |
| 3348 | 517.15 | -105.53 | -53.902 | -1351.6 |
| 3349 | 423.126 | 8.5110 | -5.7681 | -11143. |
| 3350 | -128.89 | -88.410 | 2.8355 | 323.39 |
| 3351 | -421.05 | -240.81 | -2.8187 | -2088.3 |
| 3352 | 798.78 | -0.3405 | 50.41.390 | -4.4190 |
| 3353 | 60.793 | 50.41.390 | -4.4190 | -188.65 |
| 3354 | 687.34 | 20.805 | -7.8308 | -1008.7 |
| 3355 | -55.153 | 495.92 | -16.316 | -515.22 |
| 3356 | 195.78 | -61.700 | -2111.9 | -7.8407 |
| 3357 | -283.80 | 15.445 | 794.79 | -3442.1 |
| 3358 | 1289.91 | 30.794 | 794.79 | -3442.1 |

CONTINUED

SESS POST1 ELEMENT STRESS LISTING SESS

LOAD STEP 1 ITERATION: 1
TIME: 0.20000

| ELEM | FX | FY | FZ | SDIR |
|------|---------|----------|----------|---------|
| 3359 | 1678.0 | 10.851 | 10.933 | -4410.2 |
| 3360 | -410.2 | -813.23 | 880.97 | -51.145 |
| 3361 | 198.53 | 8.8080 | 430 | -522.44 |
| 3362 | -618.94 | 8.2485 | 1.9715 | 11892. |
| 3363 | -114.25 | 0.55059 | -2.0270 | 309.65 |
| 3364 | 1506.4 | 174.22 | -5.2501 | -4172.0 |
| 3365 | 107.487 | -14.742 | 25.748 | -284.17 |
| 3366 | 107.487 | -14.742 | 25.748 | -284.17 |
| 3367 | -61.14 | -0.30428 | -0.44816 | 1189.3 |
| 3368 | -1798.3 | -1.0053 | -0.84261 | 4732.2 |
| 3369 | -1309.3 | 26.376 | -12.261 | 3421.8 |
| 3370 | 2149.8 | -0.3412 | -2.2805 | -5457.7 |
| 3371 | 2149.8 | -0.3412 | -2.2805 | -5457.7 |
| 3372 | -200.77 | 5.0675 | -3.0095 | 378.61 |
| 3373 | 279.81 | 27.33 | 349.49 | 485.96 |
| 3374 | -279.81 | 27.33 | 349.49 | 485.96 |
| 3375 | 325.90 | 12.364 | -1.0609 | 684.17 |
| 3376 | 325.90 | 12.364 | -1.0609 | 684.17 |
| 3377 | -110.48 | 0.48007 | -1.1821 | 203.49 |
| 3378 | 1.2811 | 0.58303 | | |

SESS POST1 ELEMENT STRESS LISTING SESS

LOAD STEP 1 ITERATION: 1
TIME: 0.20000

| ELEM | FX | FY | FZ | SDIR |
|------|---------|--------|--------|--------|
| 3379 | -83.959 | 14.167 | 0.5636 | 45.206 |

| ELEM | FX | FY | FZ | SDIR |
|------|----------|---------|---------|---------|
| 3380 | -197.107 | 81.849 | 11.034 | 0.41004 |
| 3381 | -197.107 | 81.849 | 11.034 | 0.41004 |
| 3382 | -194.84 | -4.0187 | -4.6700 | -343.00 |
| 3383 | -194.84 | -4.0187 | -4.6700 | -343.00 |
| 3384 | -181.318 | -89.318 | -41.614 | 809.05 |
| 3385 | -181.318 | -89.318 | -41.614 | 809.05 |
| 3386 | -144.319 | 24.777 | 13.000 | 271.04 |
| 3387 | -144.319 | 24.777 | 13.000 | 271.04 |
| 3388 | -97.838 | 8.8105 | 3.9400 | 184.63 |
| 3389 | -97.838 | 8.8105 | 3.9400 | 184.63 |
| 3390 | -87.372 | 14.407 | 0.0001 | 164.06 |
| 3391 | -87.372 | 14.407 | 0.0001 | 164.06 |
| 3392 | -64.770 | -0.0011 | -0.3646 | 124.88 |
| 3393 | -64.770 | -0.0011 | -0.3646 | 124.88 |
| 3394 | 1402.4 | 11.062 | 0.5306 | -2707.0 |
| 3395 | 1402.4 | 11.062 | 0.5306 | -2707.0 |
| 3396 | -104.6 | 46.337 | -37.000 | 1973.8 |
| 3397 | -104.6 | 46.337 | -37.000 | 1973.8 |
| 3398 | -80.809 | -20.248 | 86.306 | 1949.0 |
| 3399 | -80.809 | -20.248 | 86.306 | 1949.0 |
| 3400 | 818.55 | -54.569 | -0.1306 | -1533.1 |
| 3401 | 818.55 | -54.569 | -0.1306 | -1533.1 |
| 3402 | 1340.1 | 1.0316 | -1.3870 | -8538.2 |
| 3403 | 1340.1 | 1.0316 | -1.3870 | -8538.2 |
| 3404 | -1032.8 | 8.0725 | -0.6110 | 1947.8 |
| 3405 | -1032.8 | 8.0725 | -0.6110 | 1947.8 |
| 3406 | -49.577 | 81.043 | | -517.61 |

SESS POST1 ELEMENT STRESS LISTING SESS

LOAD STEP 1 ITERATION: 1
TIME: 0.20000

| ELEM | FX | FY | FZ | SDIR |
|------|-----------|----------|----------|---------|
| 3407 | -601.81 | 30.804 | -85.137 | 1135.8 |
| 3408 | -601.81 | 30.804 | -85.137 | 1135.8 |
| 3409 | 873.51 | 89.614 | 88.978 | -1270.8 |
| 3410 | 873.51 | 89.614 | 88.978 | -1270.8 |
| 3411 | -1408.973 | -0.72813 | -11.316 | 8653.0 |
| 3412 | -1408.973 | -0.72813 | -11.316 | 8653.0 |
| 3413 | 1968.4 | -80.847 | 0.8077 | -3683.8 |
| 3414 | 1968.4 | -80.847 | 0.8077 | -3683.8 |
| 3415 | -843.72 | 17.732 | 4.0860 | 8065.9 |
| 3416 | -843.72 | 17.732 | 4.0860 | 8065.9 |
| 3417 | 1025.8 | 17.013 | -14.768 | -277.77 |
| 3418 | 1025.8 | 17.013 | -14.768 | -277.77 |
| 3419 | 874.18 | -0.0028 | 0.3467 | 173.85 |
| 3420 | 874.18 | -0.0028 | 0.3467 | 173.85 |
| 3421 | -813.3 | 8.8070 | -0.84617 | 4034.5 |
| 3422 | -813.3 | 8.8070 | -0.84617 | 4034.5 |
| 3423 | 2598.3 | 0.6063 | -0.8120 | -474.64 |
| 3424 | 2598.3 | 0.6063 | -0.8120 | -474.64 |
| 3425 | -8004.040 | 1.1107 | -0.4300 | -1337.1 |
| 3426 | -8004.040 | 1.1107 | -0.4300 | -1337.1 |
| 3427 | 996.88 | -10.707 | -10.828 | 2623.5 |
| 3428 | 996.88 | -10.707 | -10.828 | 2623.5 |
| 3429 | 843.5 | 1010.8 | 1366.0 | -2301.0 |
| 3430 | 843.5 | 1010.8 | 1366.0 | -2301.0 |
| 3431 | 988.36 | 0.89061 | 1.1920 | 1455.3 |
| 3432 | 988.36 | 0.89061 | 1.1920 | 1455.3 |
| 3433 | -1800.8 | -10.028 | -15.770 | -242.64 |
| 3434 | -1800.8 | -10.028 | -15.770 | -242.64 |
| 3435 | 800.18 | 4.0178 | 0.87453 | 1184.7 |
| 3436 | 800.18 | 4.0178 | 0.87453 | 1184.7 |

SESS POST1 ELEMENT STRESS LISTING SESS

LOAD STEP 1 ITERATION: 1
TIME: 0.20000

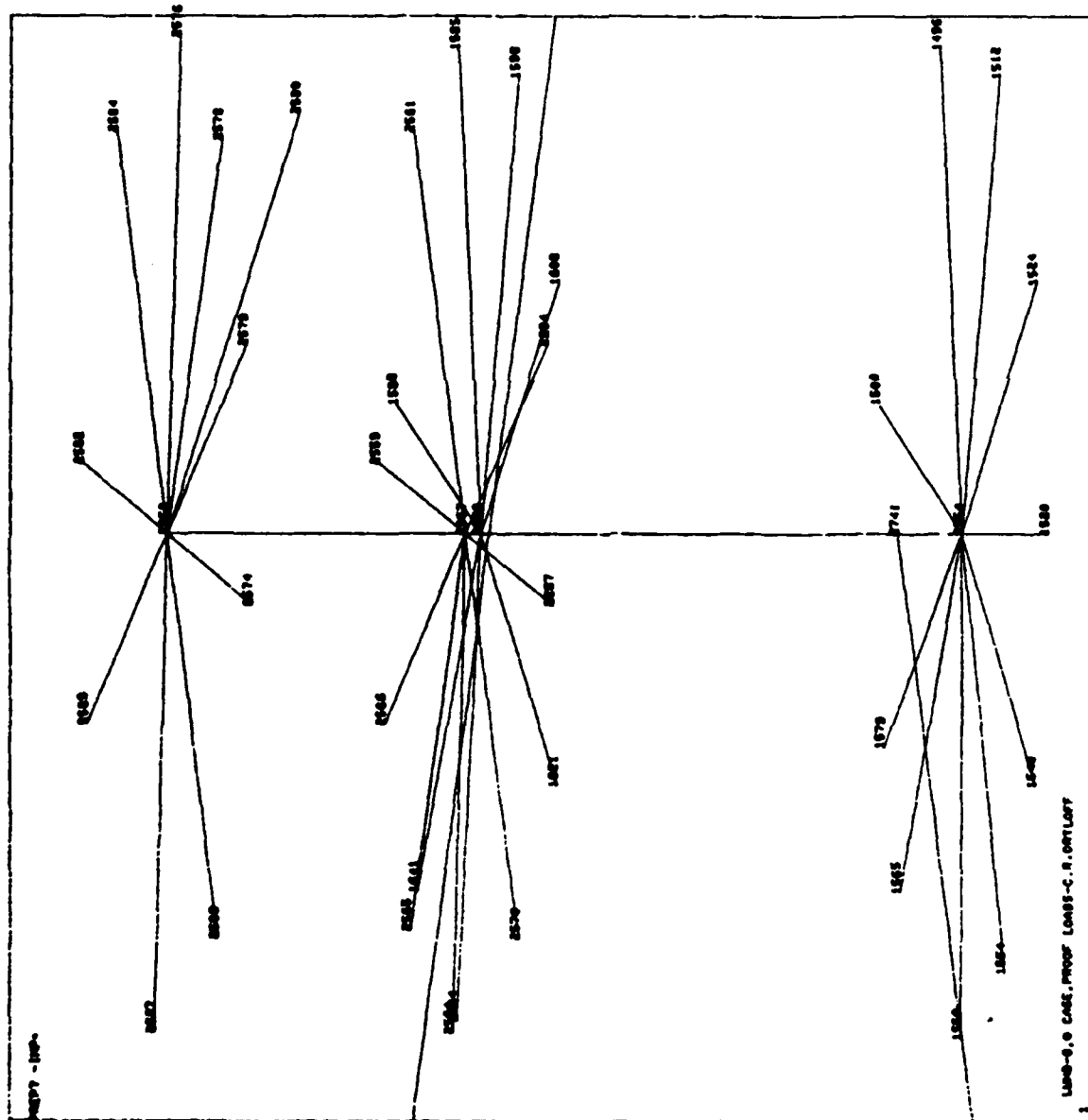
| ELEM | FX | FY | FZ | SDIR |
|------|----------|---------|---------|---------|
| 3437 | -13.333 | -8.7159 | 5499.5 | -333.63 |
| 3438 | -13.333 | -8.7159 | 5499.5 | -333.63 |
| 3439 | 2130.782 | 19.830 | -5018.3 | 1308.3 |
| 3440 | 2130.782 | 19.830 | -5018.3 | 1308.3 |
| 3441 | 91.414 | 35.820 | 1651.8 | 1061.3 |
| 3442 | 91.414 | 35.820 | 1651.8 | 1061.3 |
| 3443 | -2010.1 | -0.6047 | 3180.1 | 640.00 |
| 3444 | -2010.1 | -0.6047 | 3180.1 | 640.00 |
| 3445 | 1004.329 | 24.1078 | 89.777 | -8649.0 |
| 3446 | 1004.329 | 24.1078 | 89.777 | -8649.0 |
| 3447 | -1007.5 | 3.6378 | -2.4838 | 2794.0 |
| 3448 | -1007.5 | 3.6378 | -2.4838 | 2794.0 |
| 3449 | 1001.8 | 6.1337 | 0.7939 | -8757.8 |
| 3450 | 1001.8 | 6.1337 | 0.7939 | -8757.8 |
| 3451 | -1100.5 | -10.033 | 0.7600 | 3123.8 |

$$t = 0.28 \text{ sec}$$

267

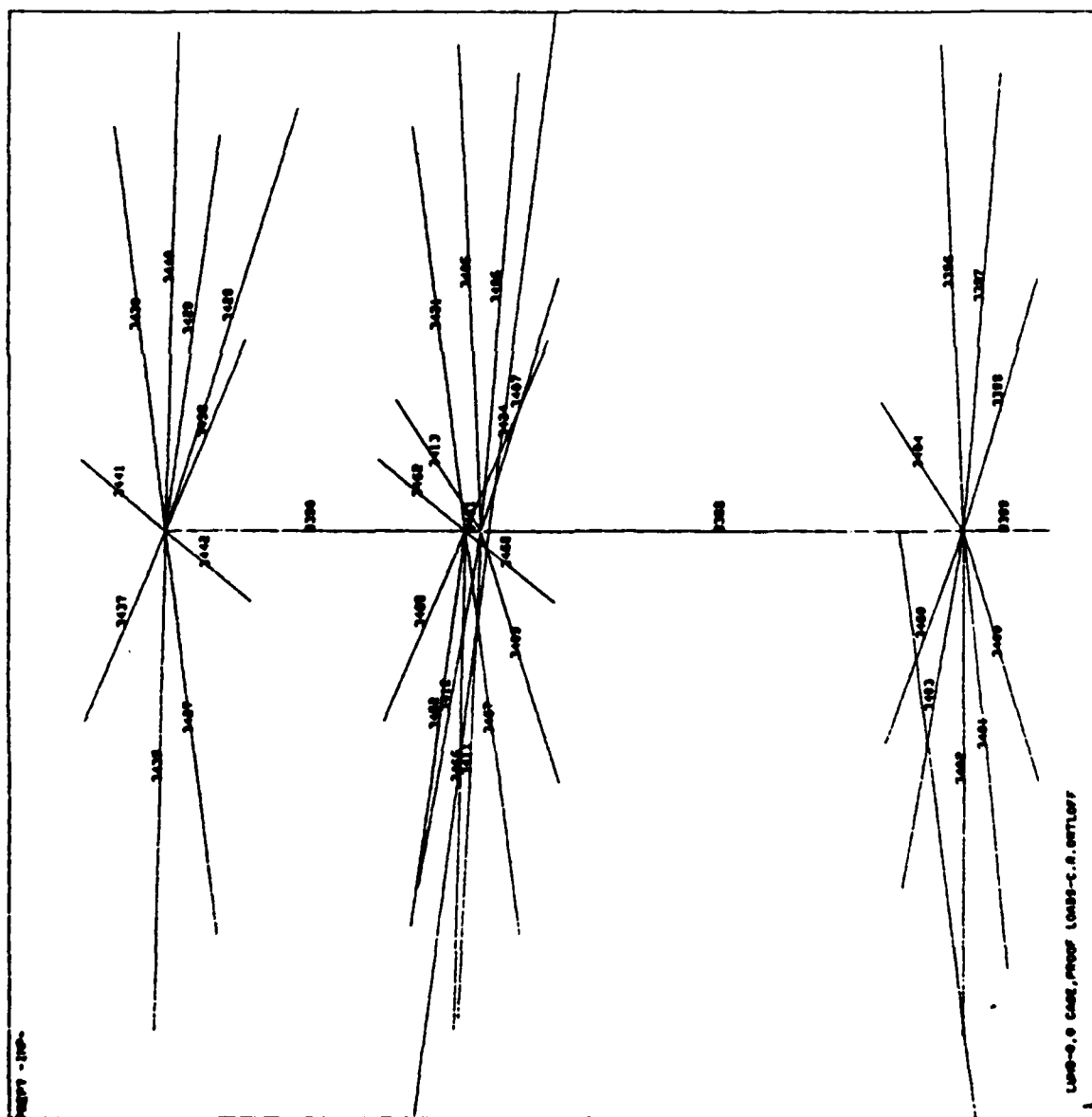
77

00000 0.00
 DEC 0 1000
 17104137
 PROPT ELEMENTS
 00000-1
 2000
 000-1
 000-1
 20-1
 0 0107-10.0
 0 07-110
 0 07-00.4
 0 07-00.6
 0000-1.30
 0000-1.32



BOTTOM

11-1-1964



270

FMC Central Engineering Laboratories Santa Clara

Interoffice

| | | | |
|---------|---|------|---|
| To | L. Libhardt* | Date | January 14, 1987 |
| From | C. R. Ortloff | cc | A. Amberg E. Thuse R. Kazares J. Ries B. Rathe B. Zierwick B. Anderson *(29 figures) |
| Subject | ESTIMATES OF THERMAL EXPANSION STRESSES IN THE LTHD CRADLE | | |

Although the composite cradle design is currently undergoing design revision in geometry, materials selection, and fabrication method, nevertheless it is instructive to determine the order of magnitude of thermally induced stress on an earlier cradle model. This earlier cradle version has many similarities to the proposed later version and represents a fall-back design should later design not prove adequate.

The wall model in the sandwich plate used for the present cradle analysis is the [0/45/-45/90/-45/45/0]_s Gr/Ep filament wound laminate for which thermal expansion coefficients (TEC) have been provided (LL to CR0). The provided (TEC) value has been cross-checked with results from the UCLA Seminar Notes "Design Technology and Applications of Composites Engr. 847.34, P. K122, K162-165, 1982) and found to be in reasonable agreement for the given stacking sequence. Results for a 100°F temperature excursion over ambient (70°F) are summarized below. The nomenclature used to describe the cradle lamina sequence as given in a previous memo (CR0 to R. Rathe, 8-Dec-86) is used. As before, the ANSYS analysis program is the basis of reported results.

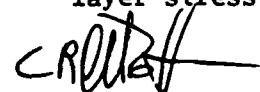
- o Maximum thermal expansion stresses exceeding 10 ksi in the fiber direction appear in: lamina 3 (-45°, Figure 475); lamina 7 (0°, Figure 483); lamina 8 (45°, Figure 484); lamina 9 (-45°, Figure 486); lamina 10 (90°, Figure 488); lamina 11 (-45°, Figure 490) and lamina 12 (45°, Figure 493). Of these, the lamina 10 stress (16 ksi) is the largest (Figure 488).
- o While many high stress regions occur around the manifold to inner Gr/Ep layer interface zones (Figure 486, for example), high stresses over 10 ksi occur over most of the cradle for lamina 10 (90°, Figure 488). The selection of a proper clearance value between the second manifold and the inner Gr/Ep layer should help to relieve the locally high contact stress levels. The first manifold joint, however, appears to experience high (16.9 ksi) stress due to the mismatch between Ti

L. Libhardt
Estimates of Thermal Expansion Stresses
in the LTHD Cradle

January 14, 1987
Page 2

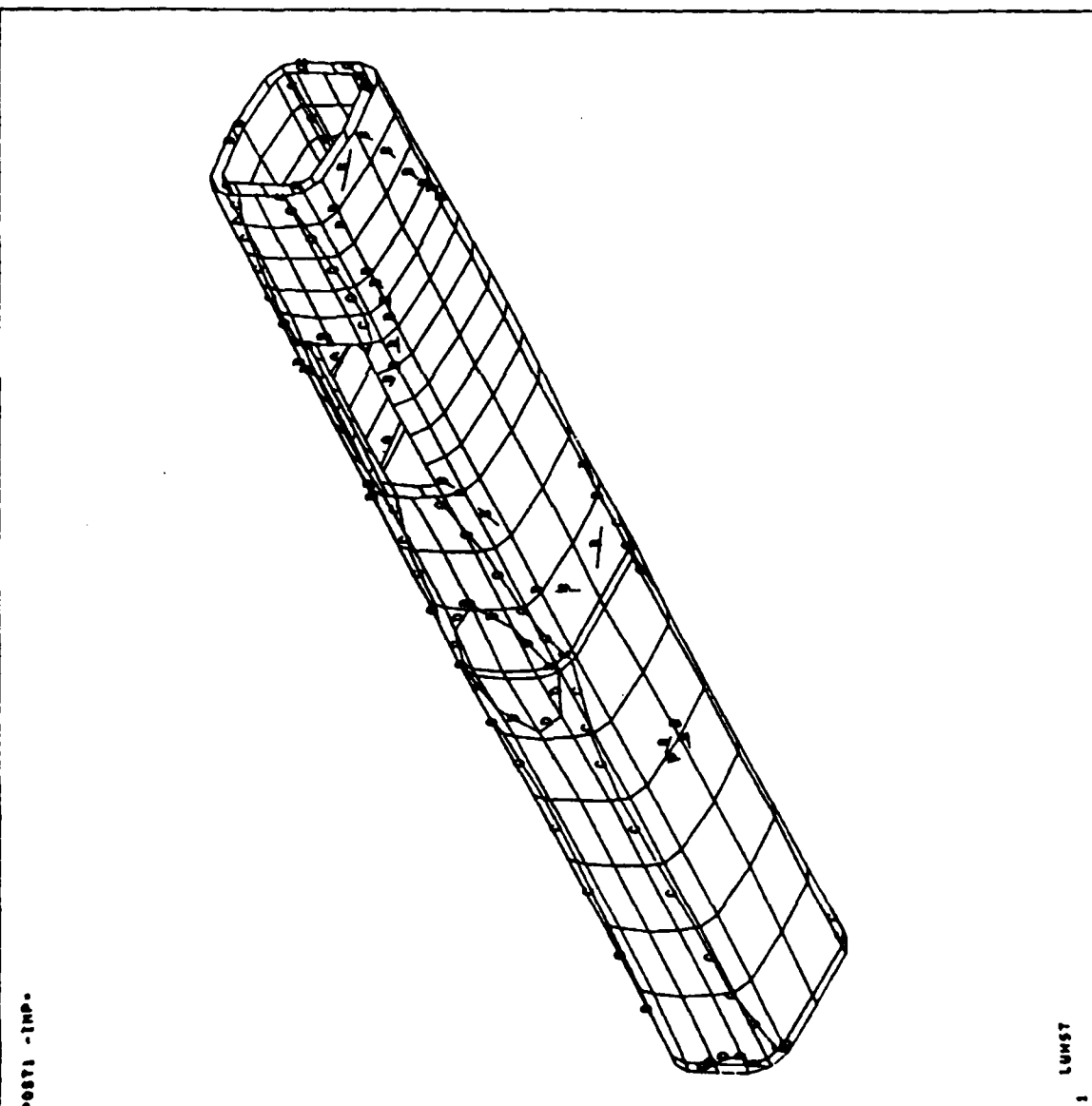
and Gr/Ep thermal expansion coefficients (3 to 4X). These additional thermal stresses should be taken into account for the forward joint design as the joint interface may not show much Gr yielding under dynamic loading and undergo brittle failure. The joint needs special design considerations and possible use of buffer strips. Stresses are large in the vicinity of the cradle cut-outs for certain lamina (see, for example, Figures 475, 484, 486, 488 and 493).

- o A rough calculation of compressional fiber buckling stress using the CMAP equivalent modulus in the load direction indicates that there may be local fiber buckling or crippling near the first manifold joint under the proof impulse loads (for the "old" filament wound cradle design). A layered beam column FE model under compressive impulse loads would be constructive to investigate local stability. Although buckling stress or load prediction is very approximate, nonetheless, this forward joint zone should be analyzed with local FE detailed models.
- A comparison of the University of Delaware CMAP thermal stress program results (Memo: CRO to L. Libhardt 22-Dec-86) to present detailed thermal stress ANSYS results confirms that thermal stresses as high as 15 ksi may occur within the cradle laminate. The presence of hygrothermal (moisture absorption loads) is not considered in the present analysis but can result in a reduction in modulus (10-15%), softening of the epoxy resulting in a lowering of failure criteria epoxy stress values and induced stress (due to swelling) within the laminate. These stresses can be on the order of several thousand psi as indicated by the CMAP results.
- o Decreases in temperature may cause contractions and local curvature changes in the Gr/Ep cradle laminate such as to bind the second manifold to the interior wall of the cradle. The sliding motion of the manifold will therefore be impeded if the clearance is too small. A FE model analysis can predict temperature contraction effects to decide the appropriate Gr/Ep inner wall-to-manifold plate clearance.
- o Use of layered Gr/Ti sheets to compose cradle end joints (to connect to the gimbal) should be analyzed for thermal expansion layer stress as the CTE for each material differs widely.



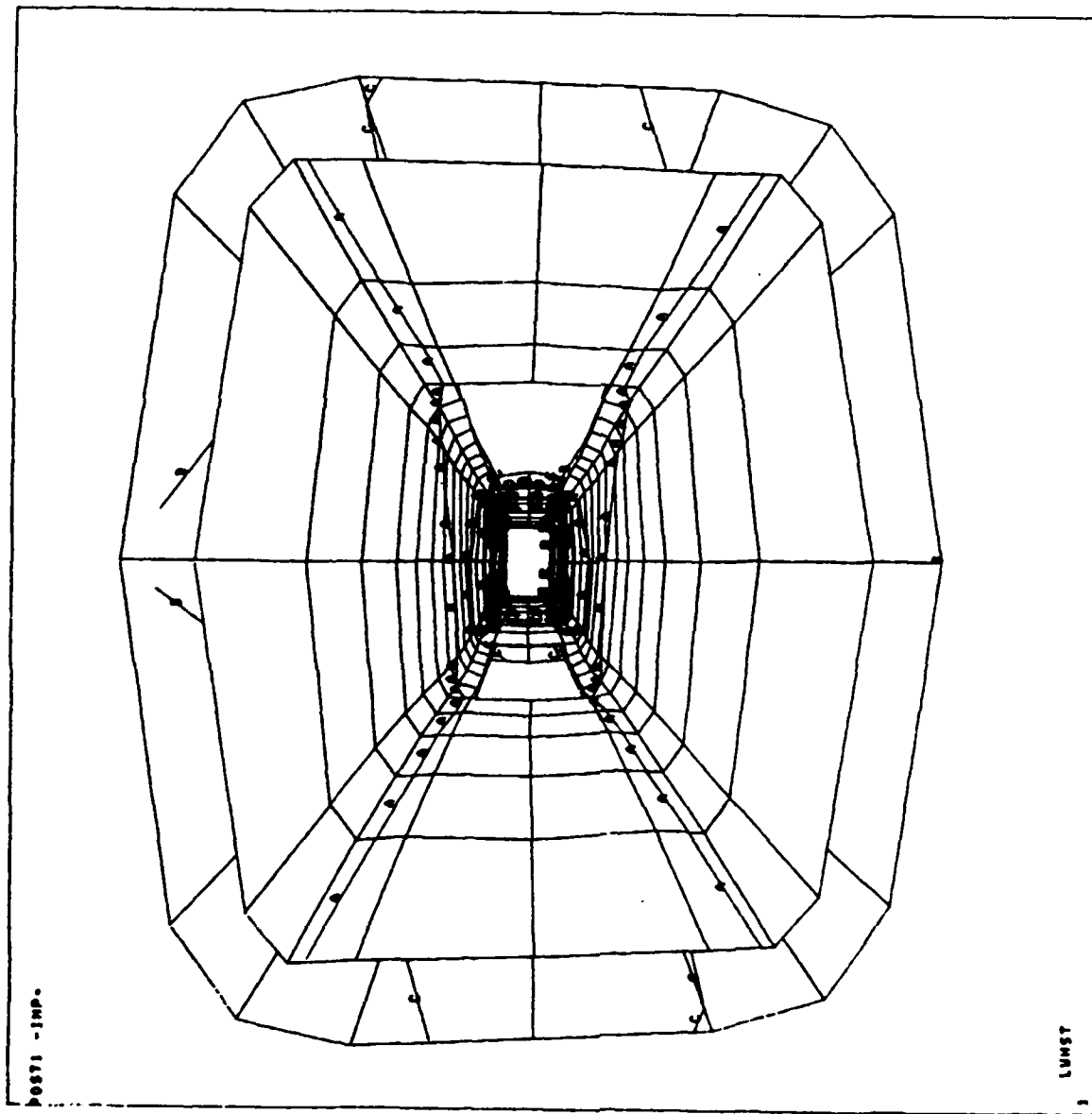
C. R. Ortloff

ANSYS 4.28
 JAN 13 1987
 15128149
 POST1 STRESS
 STEP=1
 LAYER=1
 SKI
 XU=-1
 YU=-1
 ZU=1
 DIST=104
 ZF=116
 HIDDEN
 RK=8146
 RN=-4306
 A=-2232
 B=-156
 C=1020
 D=3096
 E=8072

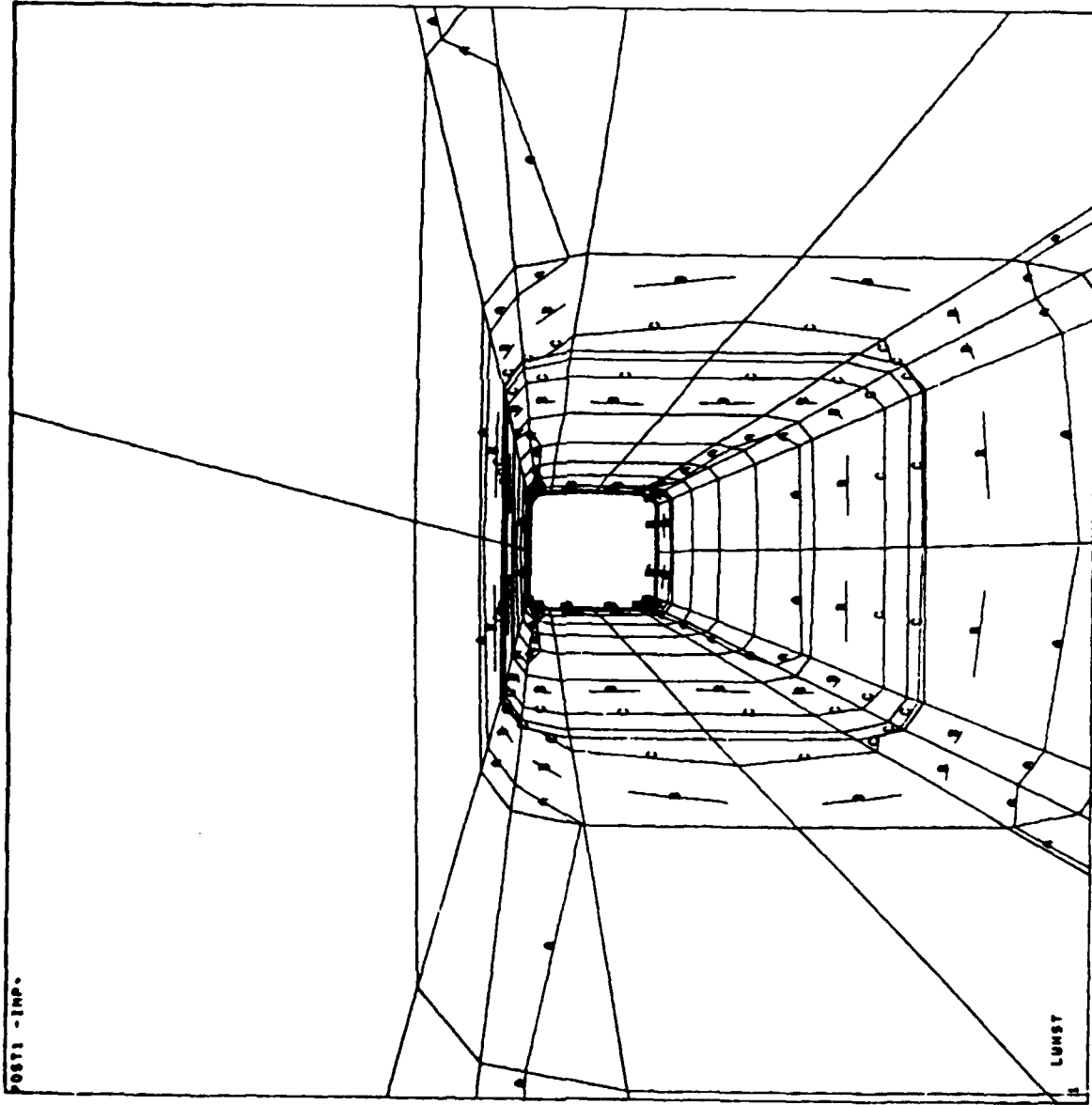


THERMAL STRESSES
 $\Delta T = 100^{\circ}F$
 FIBER DIRECTION
 LAMINA 1
 "OLD DESIGN"
 CRADLE -29
 LAYERS; WALL
 $[0/45/-45/90/-45/45/0]_S$
 G-R/EP FILAMENT
 WOUND STRUCTURE

ANSYS 4.20
JAN 13 1987
15:38:34
POST1 STRESS
STEP=1
ITER=1
SK1
ZU=1
BIST=136
ZF=116
CONE=45
HIDDEN
RX=8146
RN=4308
A=-2232
B=-156
C=1920
D=2096
E=6072

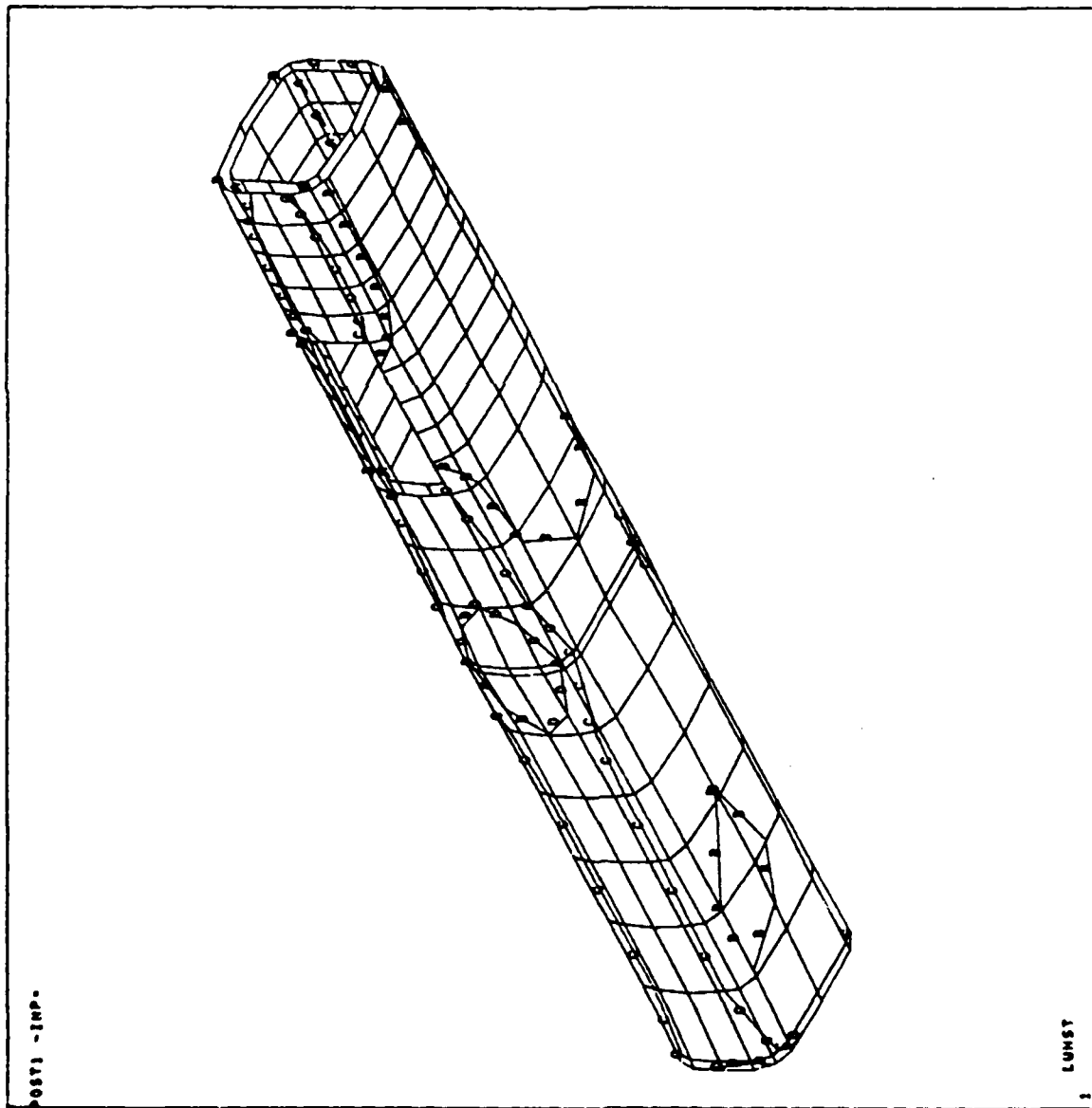


ANSYS 4.28
 JAN 13 1987
 15138124
 POST1 STRESS
 STEP=1
 ITER=1
 SNI
 ZOOM
 ZU=1
 1 DIST=36.2
 2 XF=-.87
 3 VF=8.35
 4 ZF=116
 CONE=45
 VROT=1.84
 MIDDEN
 RX=8146
 RN=-4386
 A=-2232
 B=-156
 C=1920
 D=3986
 E=6072



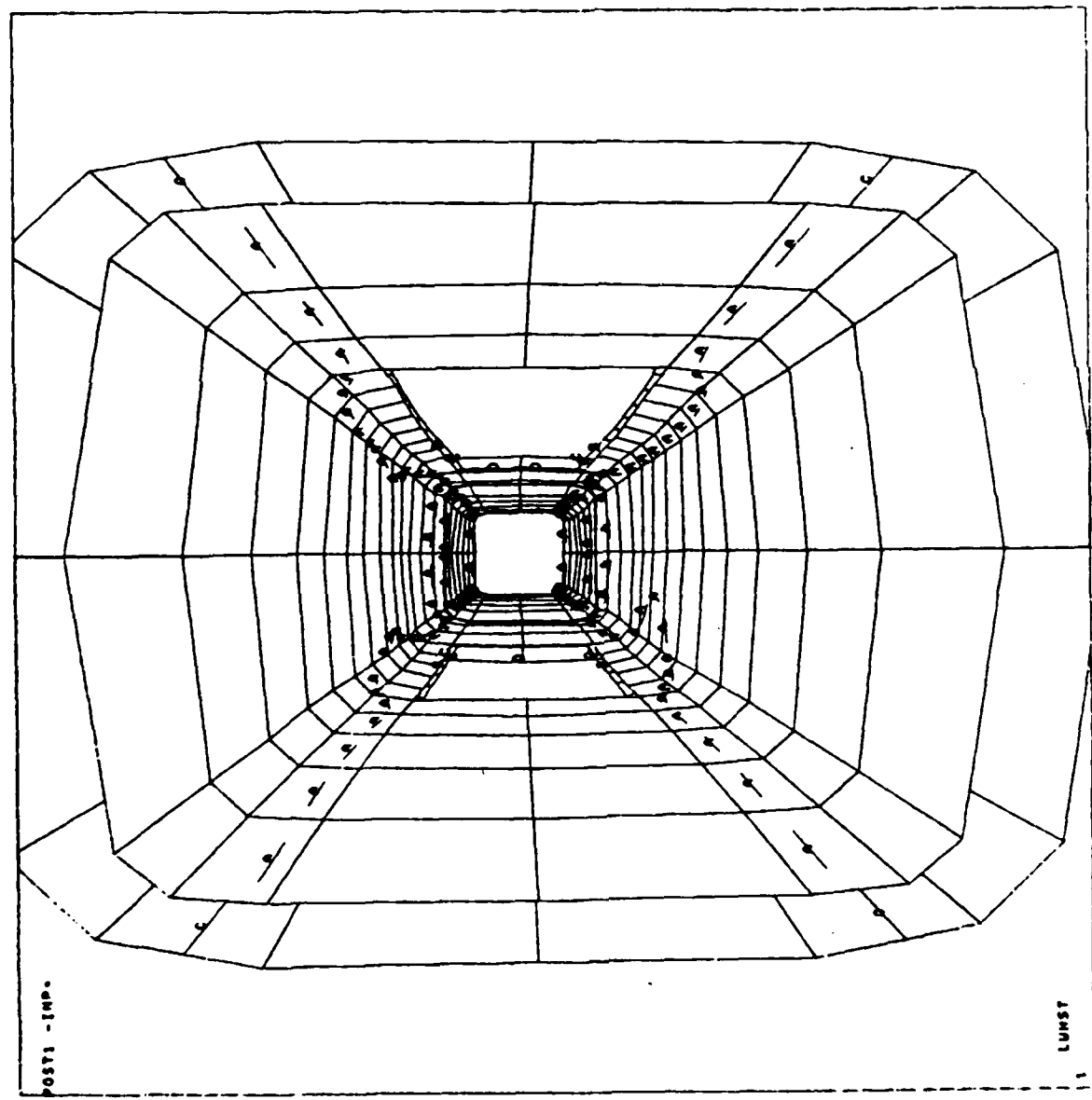
ANSYS 4.28
 JAN 12 1987
 15:33:48
 POST1 STRESS
 STEP=1
 ITER=1
 SVI
 XU=-1
 YU=-1
 ZU=1
 D197-194
 ZF-116
 HIDDEN
 MM-1119
 MM-109
 A-20
 B-240
 C-460
 D-680
 E-900

NORMAL FIBER
 DIRECTION

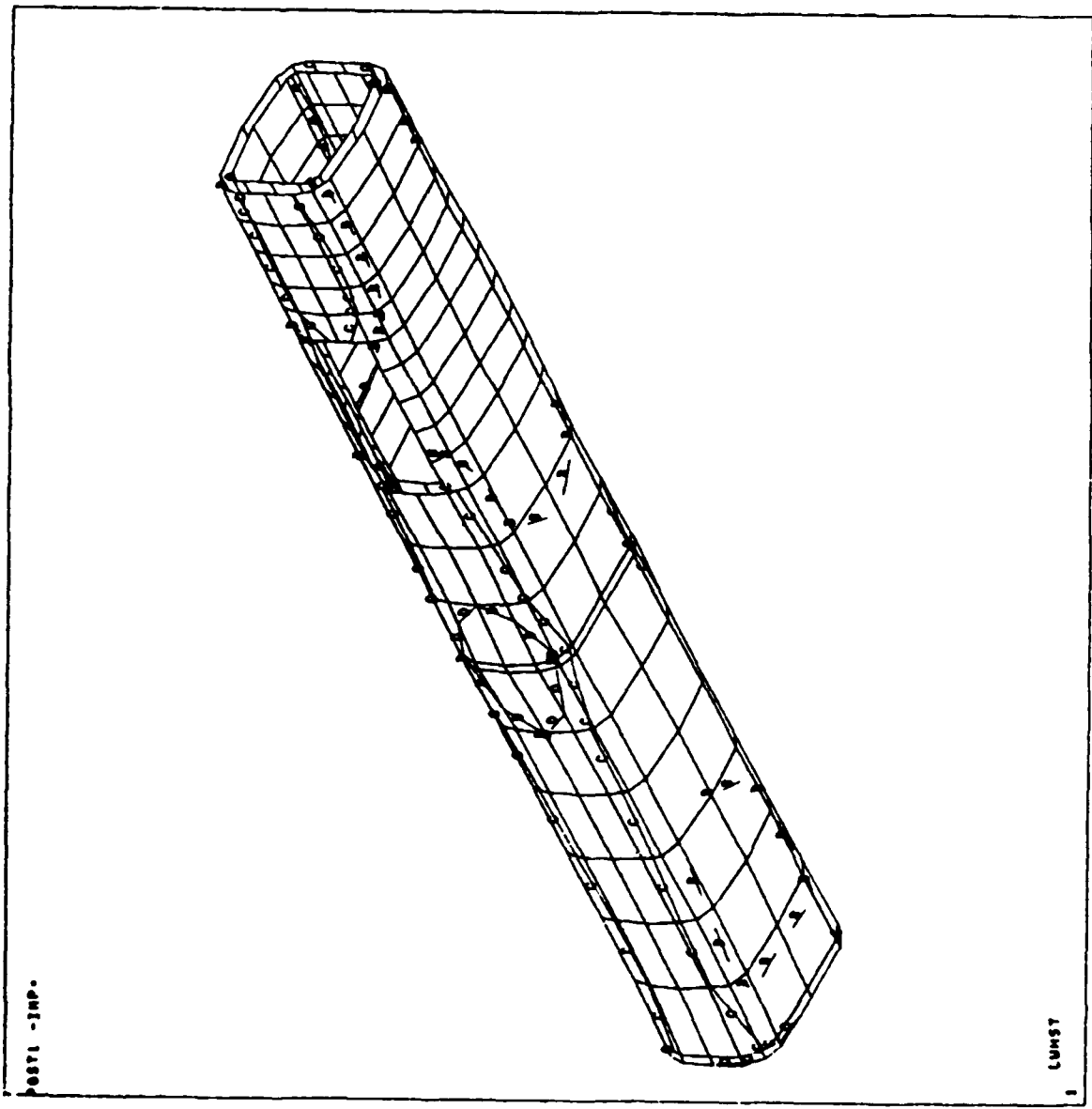


ANSYS 4.2D
JAN 13 1987
15:40:25
POST1 STRESS
STEP=1
ITER=1
SKYL
ZOOM
ZU=1
DIST=143
ZF=116
CONE=40
VRTO=1.84
MIDEN
MX=713
MY=156
A=-11.3
B=134
C=270
D=424
E=569

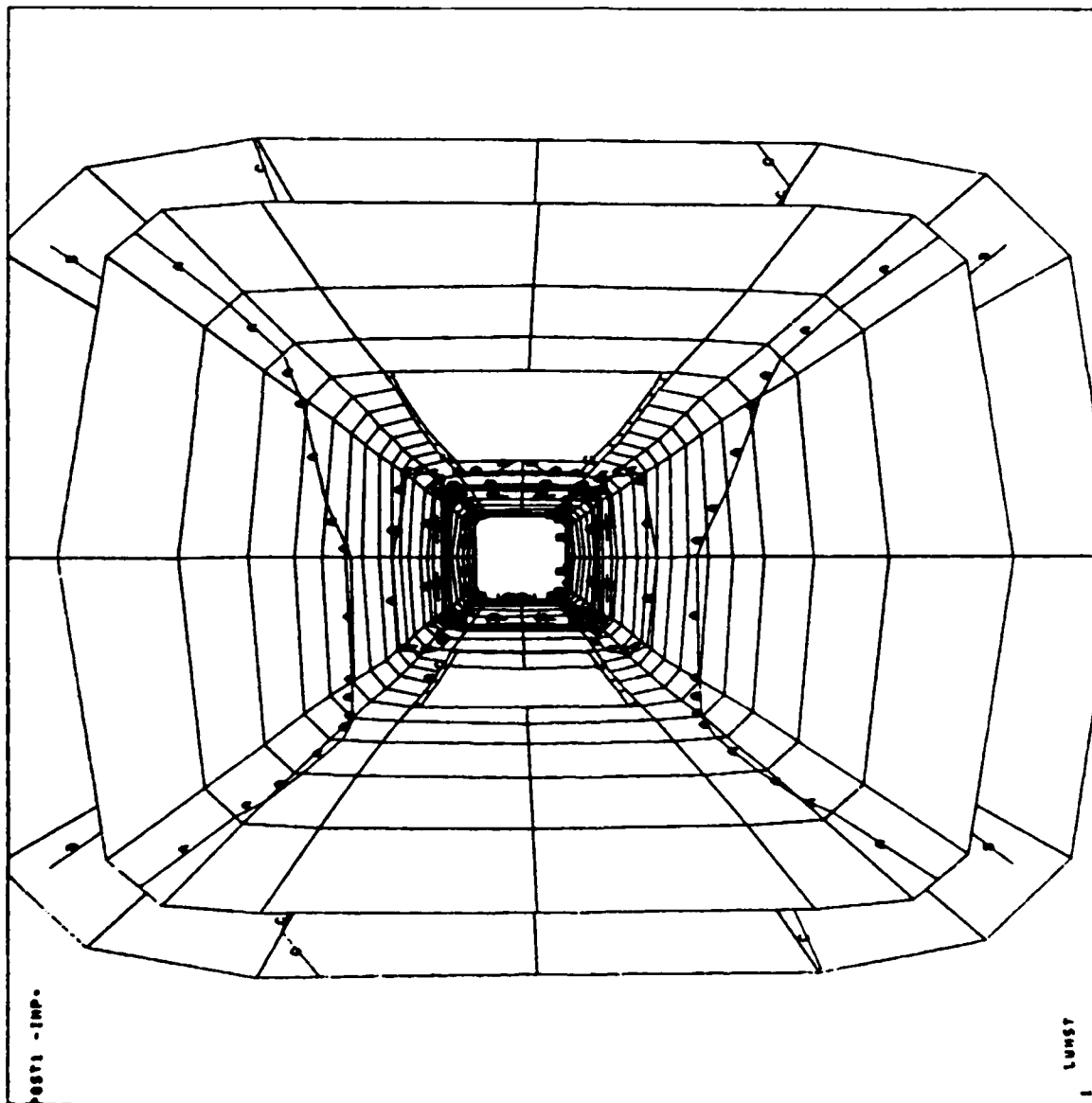
IN PLANE
SHEAR
STRESS



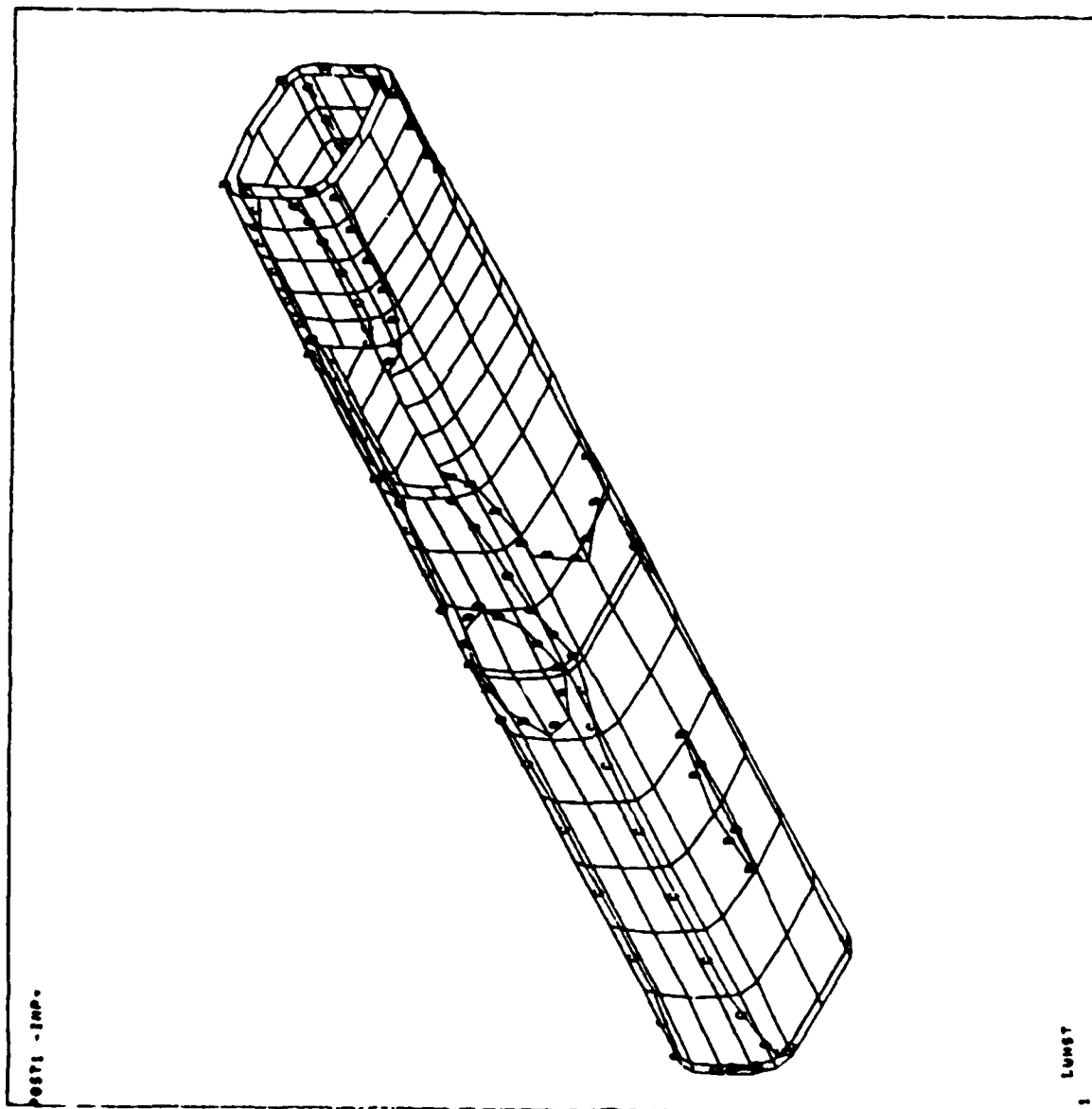
ANSYS 4.28
JAN 13 1987
15:30:18
POST1 STRESS
STEP=1
ITER=1
SHE
K0=1
V0=1
Z0=1
DIST=104
ZF=118
WIDEN
HX=8095
HM=4297
A=2233
B=167
C=1899
D=3965
E=6031



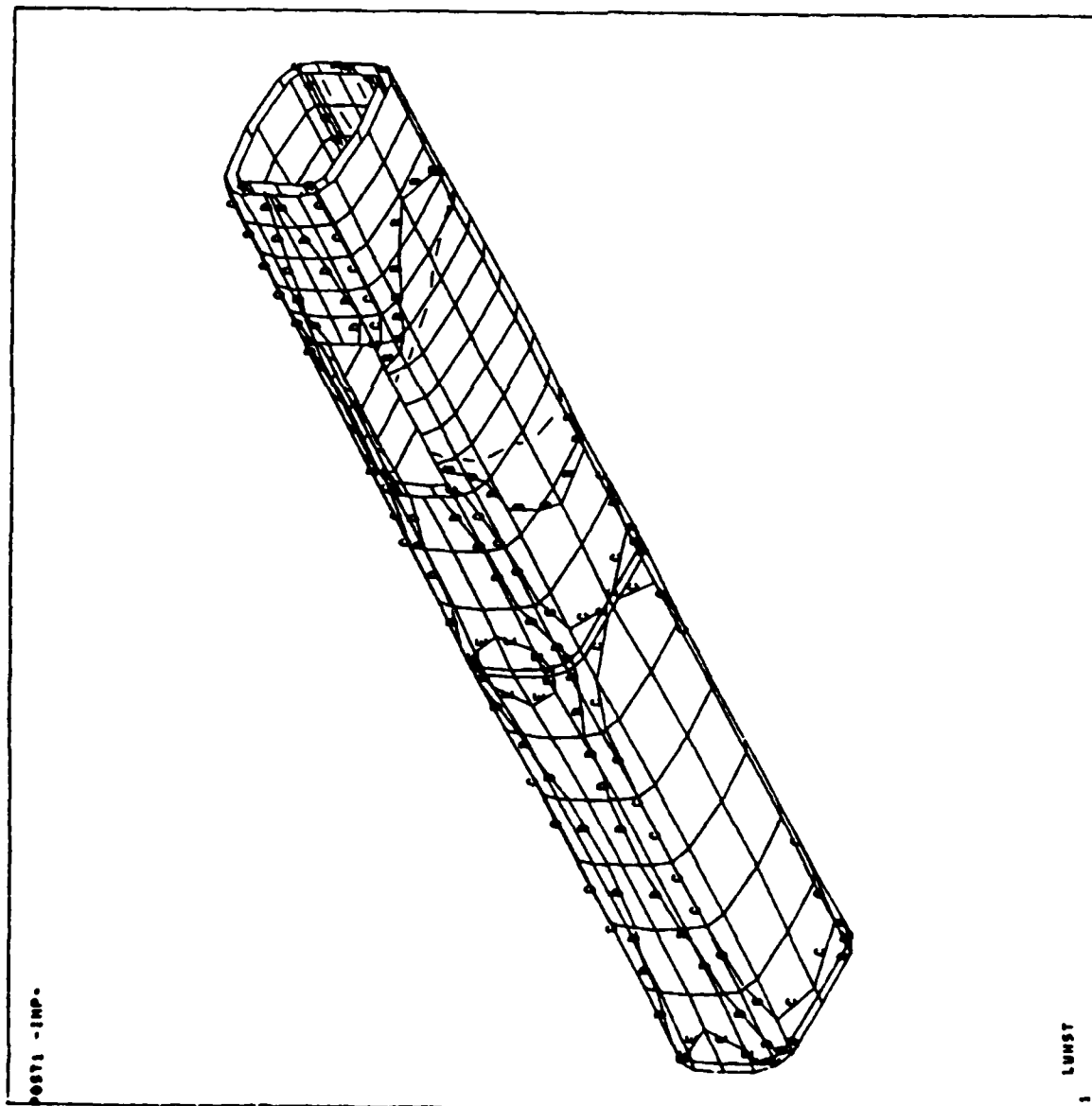
ANSYS 4.28
 JAN 13 1987
 15146118
 POST1 STRESS
 STEP=1
 ITER=1
 SK2
 ZOOM
 ZU=1
 0187.193
 2F-116
 CONE-40
 VRT0-1.84
 MIDDLEM
 RX-8095
 RM-4287
 A--2233
 B--167
 C-1899
 D-3965
 E-8831



ANSYS 4.80
 JAN 13 1987
 15125127
 POST1 STRESS
 STEP=1
 ITER=1
 SVE
 MU=-1
 VU=-1
 ZU=1
 DIST=104
 ZF=110
 MIDDEM
 RM=1100
 MM=-202
 A=15.6
 B=235
 C=454
 D=673
 E=892

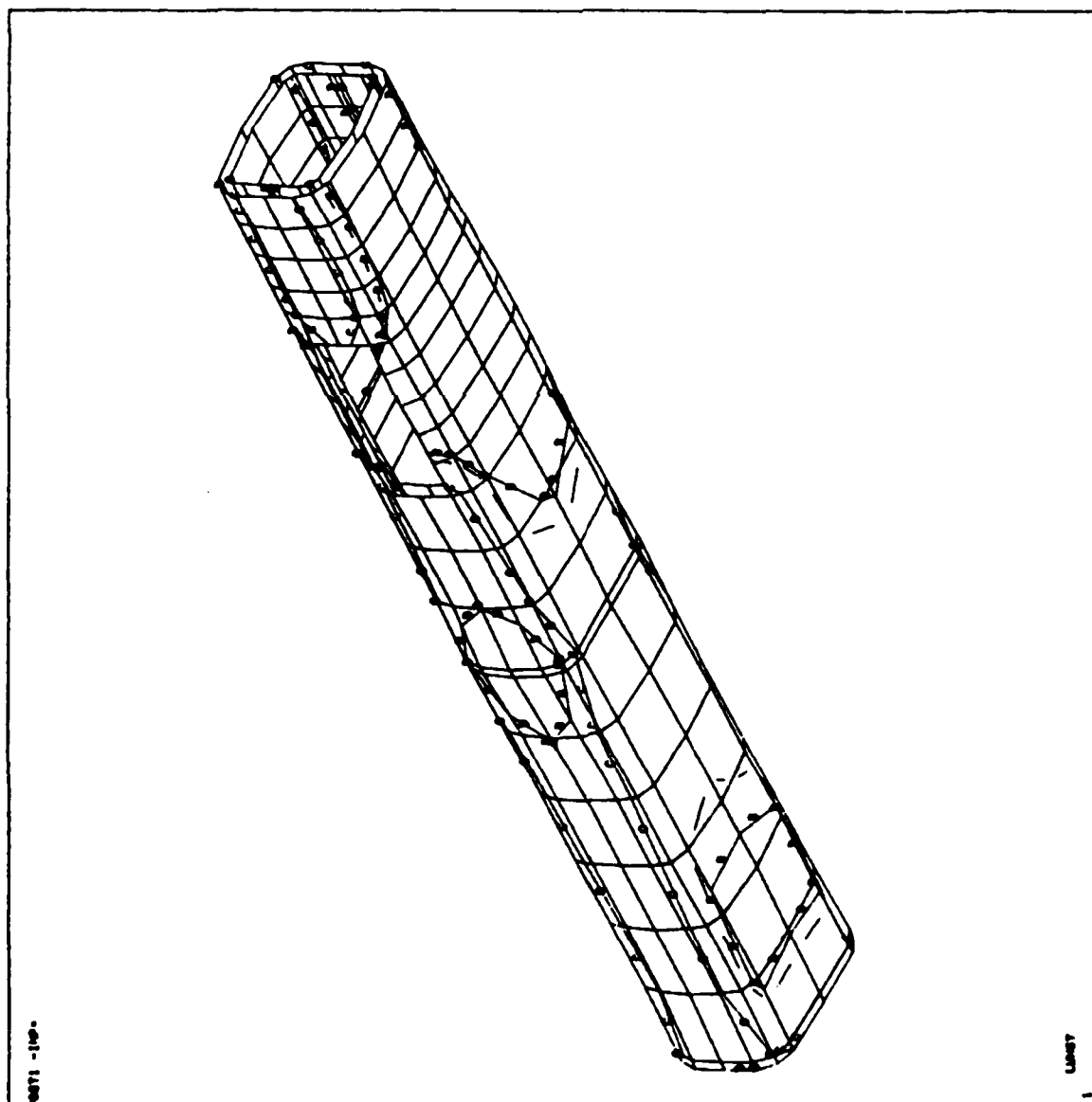


ANSYS 4.2B
 JAN 13 1987
 15:32:02
 POST1 STRESS
 STEP=1
 IYER=1
 SXS
 KU=-1
 VU=-1
 ZU=1
 DIST=104
 ZF=116
 MID2M
 RX=14300
 RN=-5305
 A=-8639
 B=1820
 C=4497
 D=7765
 E=11033



3
475

ANALYSIS 4.25
JAN 13 1987
18110104
PART1 STRESS
STEP=1
ITER=1
END
NO=1
VW=1
ZU=1
DIST=104
ST=116
M10007
PC=7007
PC=4344
A=2301
B=205
C=1701
D=2037
E=8003



ANSYS 4.28

JAN 13 1987

16152107

POST1 STRESS

STEP=1

ITER=1

SK1

ZOOM

ZU=1

1 DIST=55.5

1 XF=6.16

1 YF=11.2

1 ZF=116

1 CONE=40

1 VRTO=1.48

1 MIDDEN

1 MX=7927

1 MY=4344

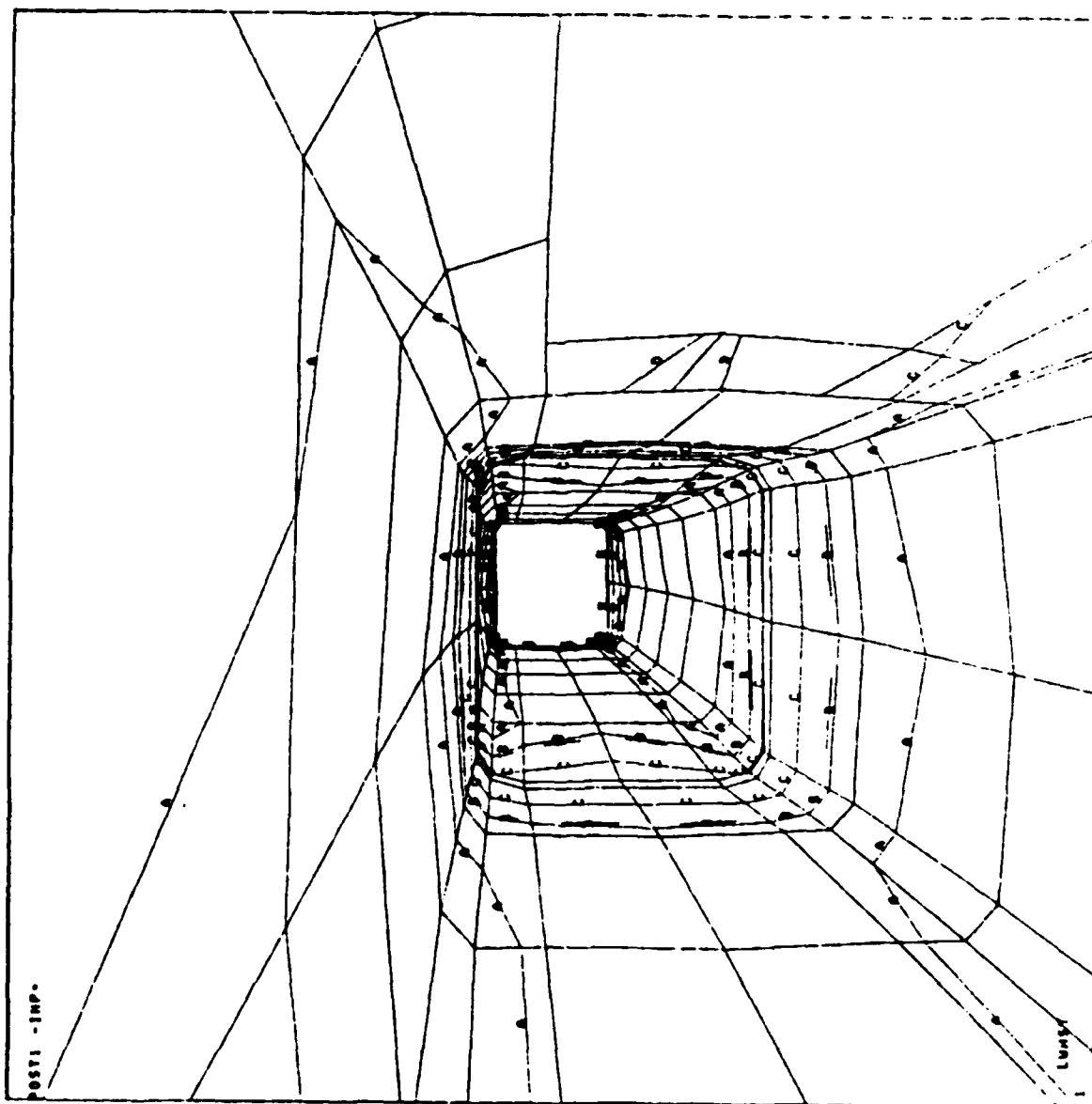
1 MZ=2301

1 B=255

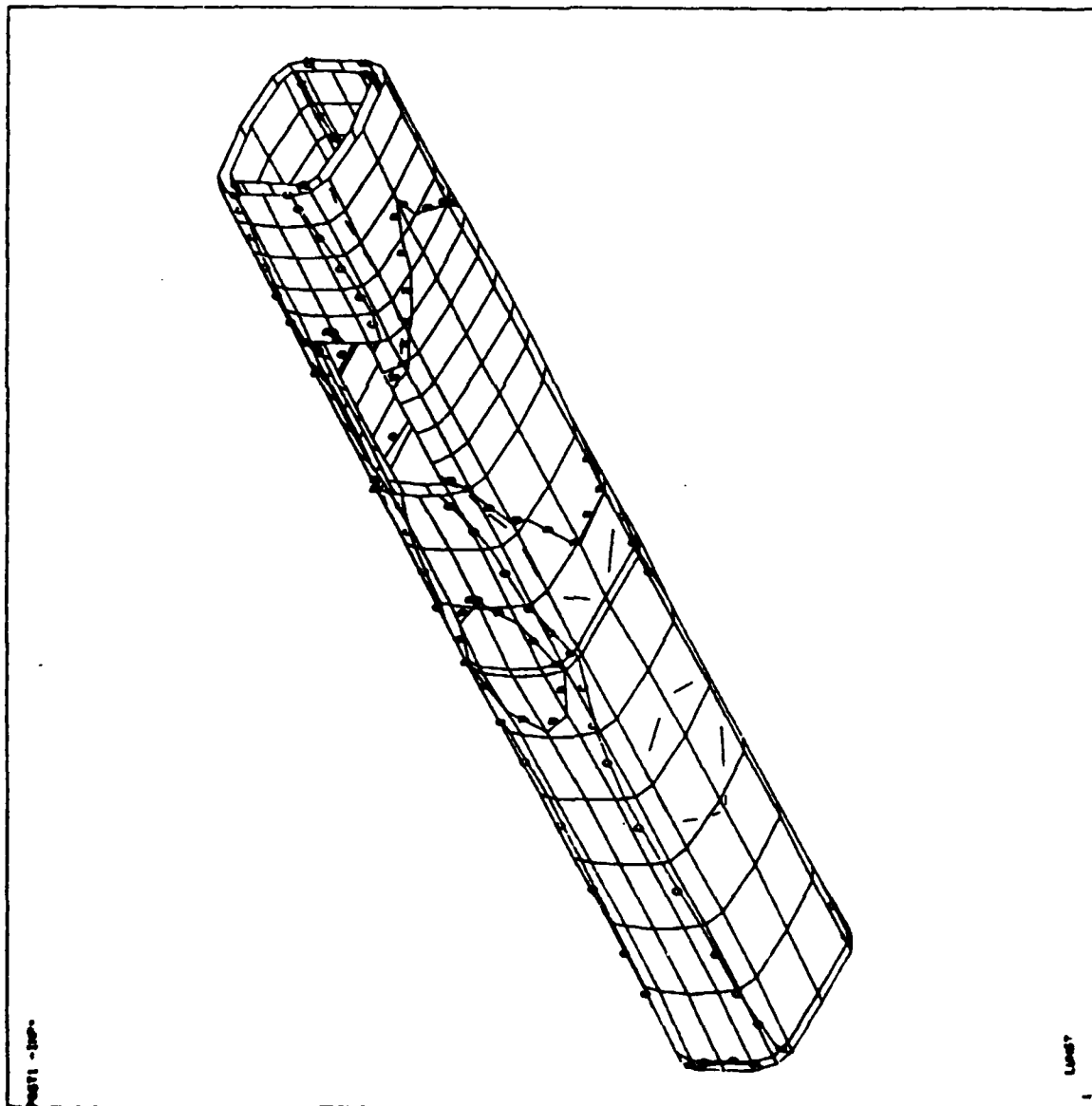
1 C=1791

1 D=3837

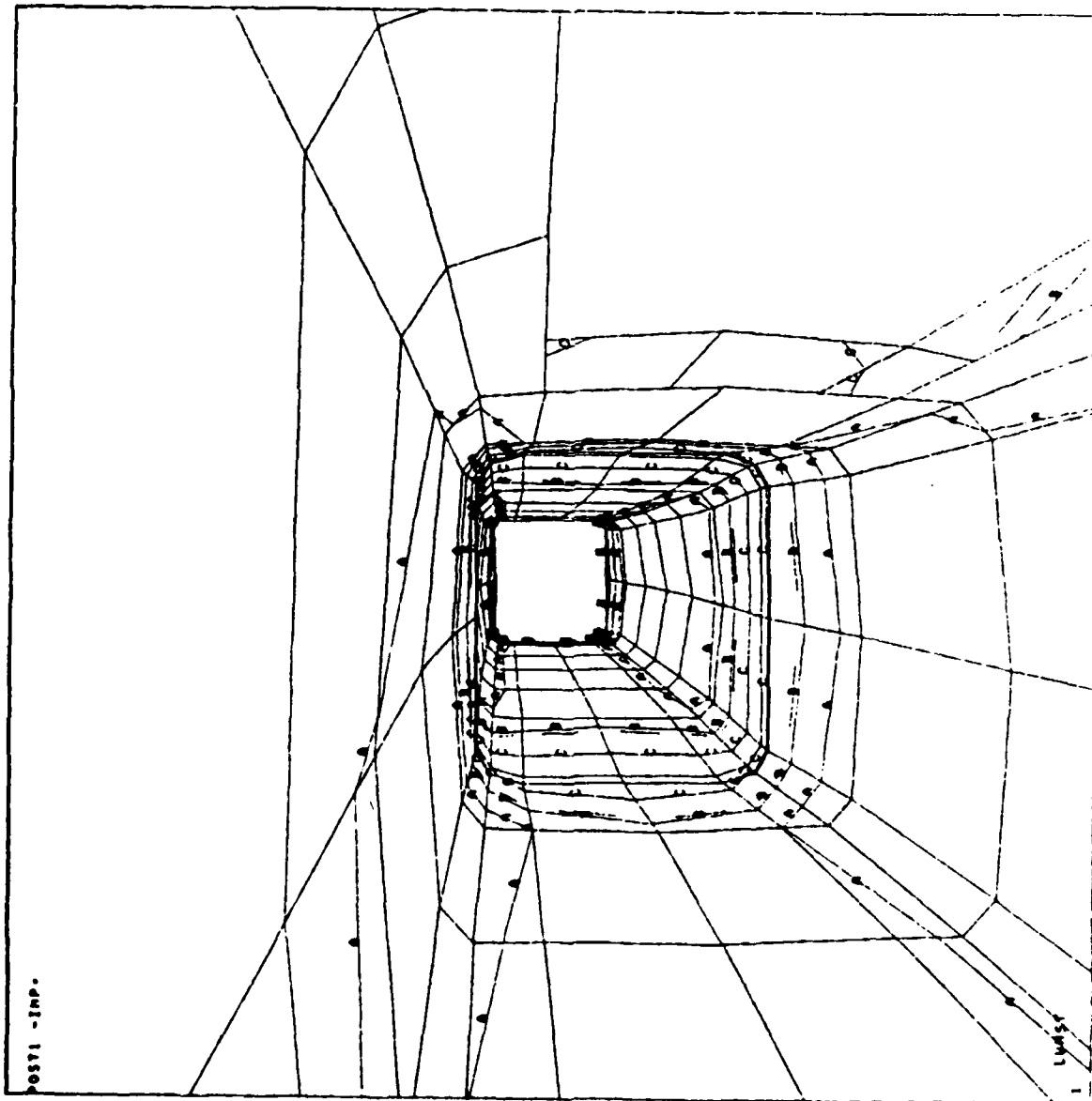
1 E=5883



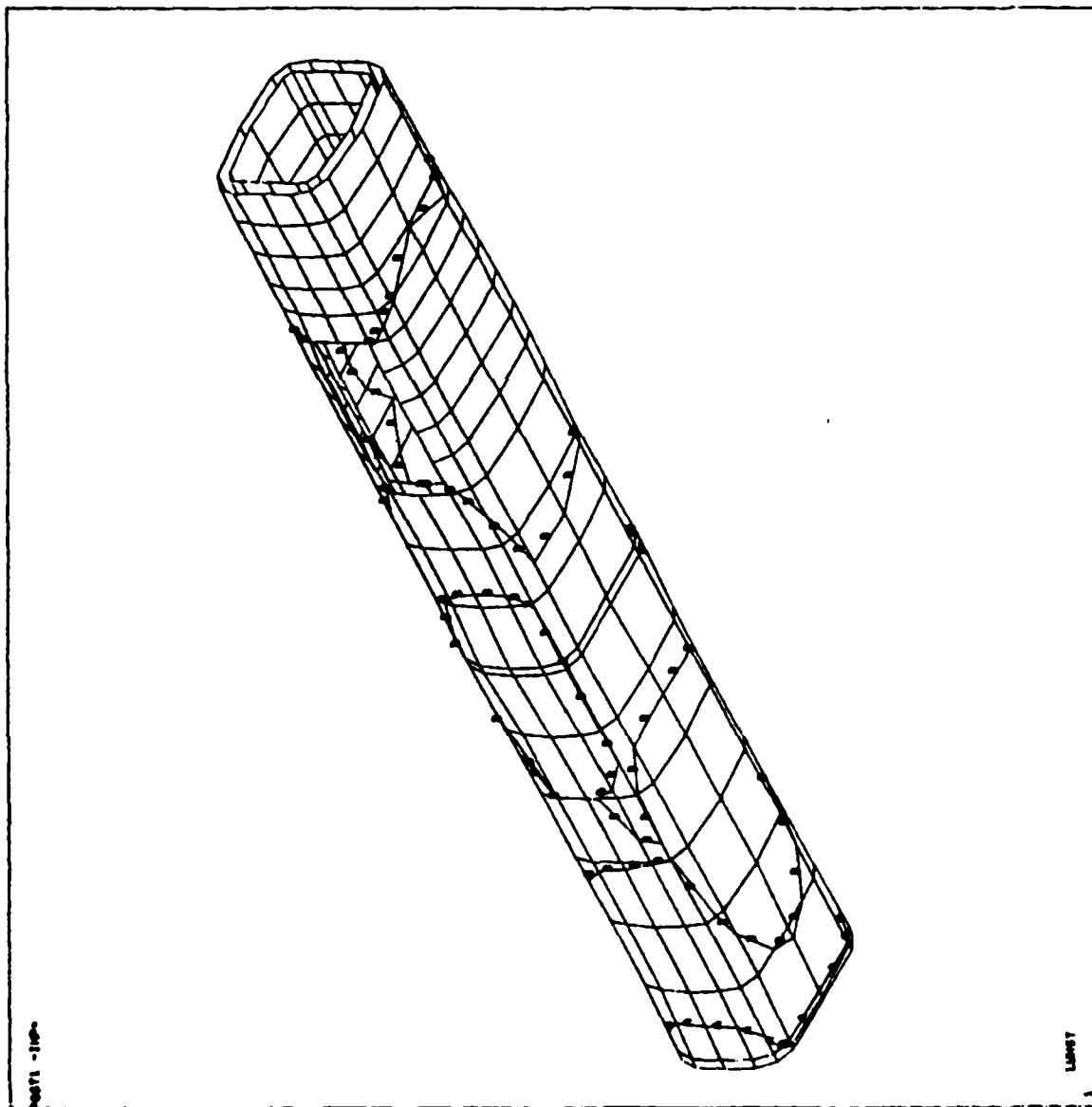
AUGUS 4.20
 JAN 13 1987
 15112-60
 POST1 STESS
 STEP=1
 IYER=1
 END
 10--1
 10--1
 20--1
 315--104
 35--116
 418024
 60-7018
 60--4204
 6--4751
 9--317
 C-1717
 D-3761
 E-9785



ANSYS 4.20
 JAN 13 1987
 16:50:48
 POST1 STRESS
 STEP=1
 ITER=1
 SHS
 ZOOM
 ZU=1
 1 DIST=55.5
 2 XP=6.16
 3 YF=11.2
 4 ZF=11.6
 CONE=40
 VROT=1.48
 HIDDEN
 RM=7818
 RM=-4284
 A=-2351
 B=-317
 C=1717
 D=3751
 E=5785



ADDS 4.20
 JAN 12 1987
 10114077
 POST1 STRESS
 STEP=1
 ITER=1
 END
 NO=1
 NO=1
 NO=1
 DIST=104
 ST=116
 M10029
 NO=7078
 NO=6023
 A=4300
 B=2066
 C=228
 D=2512
 E=4706



AMSVS 4.28

JAN 13 1987

16:49:31

POST1 STRESS

STEP=1

ITER=1

SK6

ZOOM

ZU=1

1 DIST=55.5

1 XF=6.16

1 YF=11.2

1 ZF=116

1 CONE=40

1 VETO=1.48

1 MIDDLE

1 RX=7078

1 MY=6623

1 A=4340

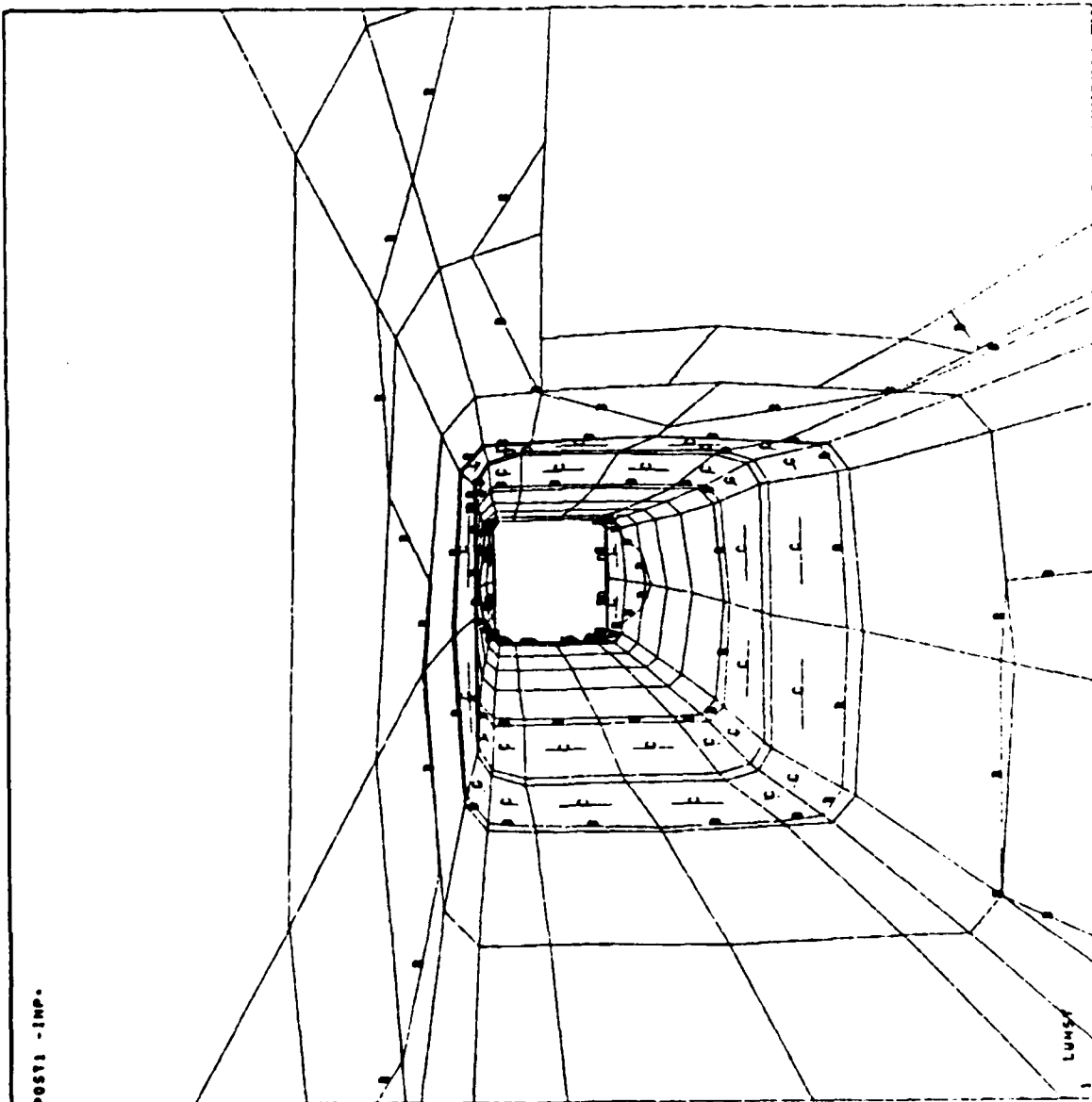
1 B=2055

1 C=228

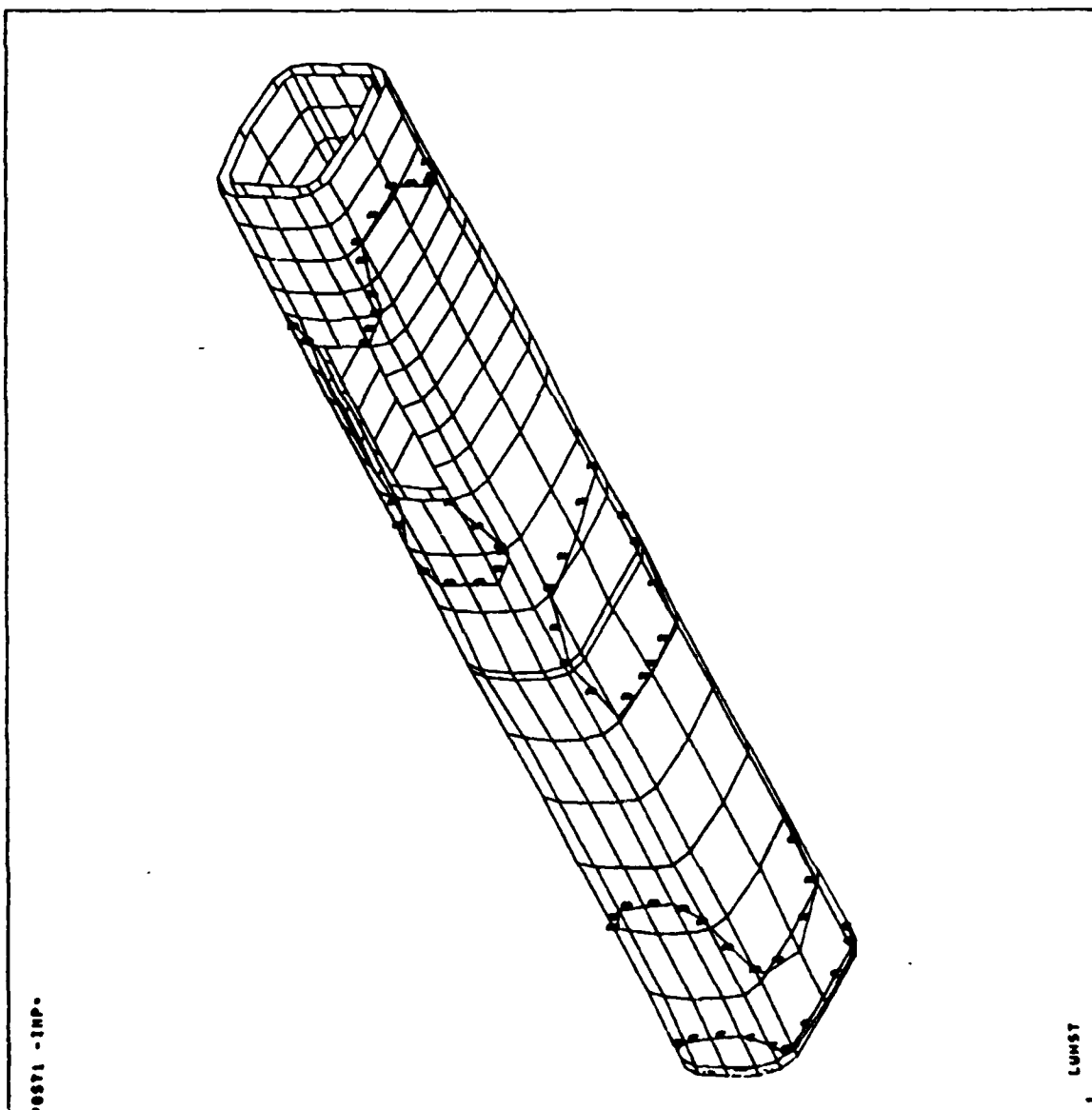
1 D=2512

1 E=4796

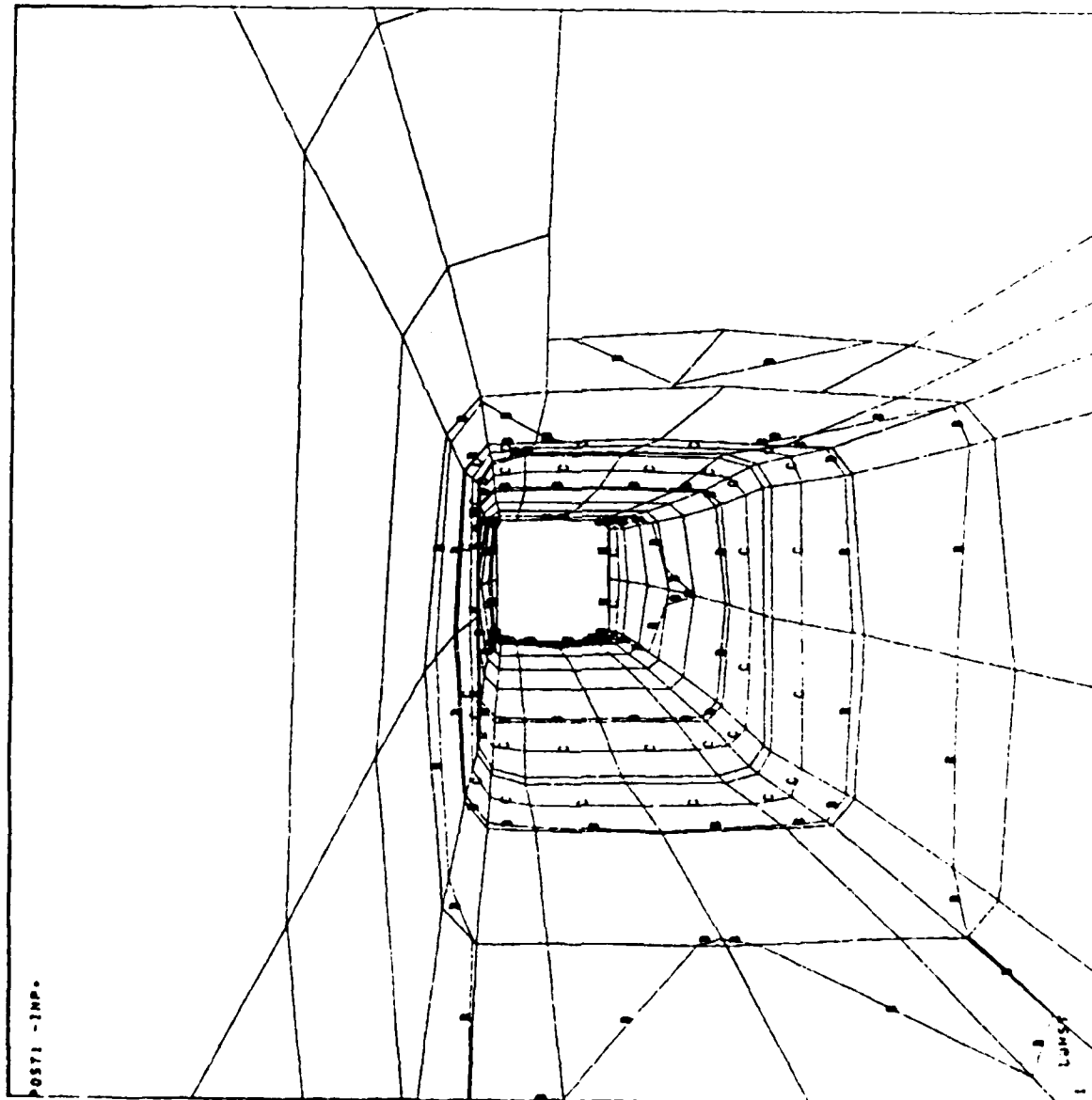
POST1 -IMP.



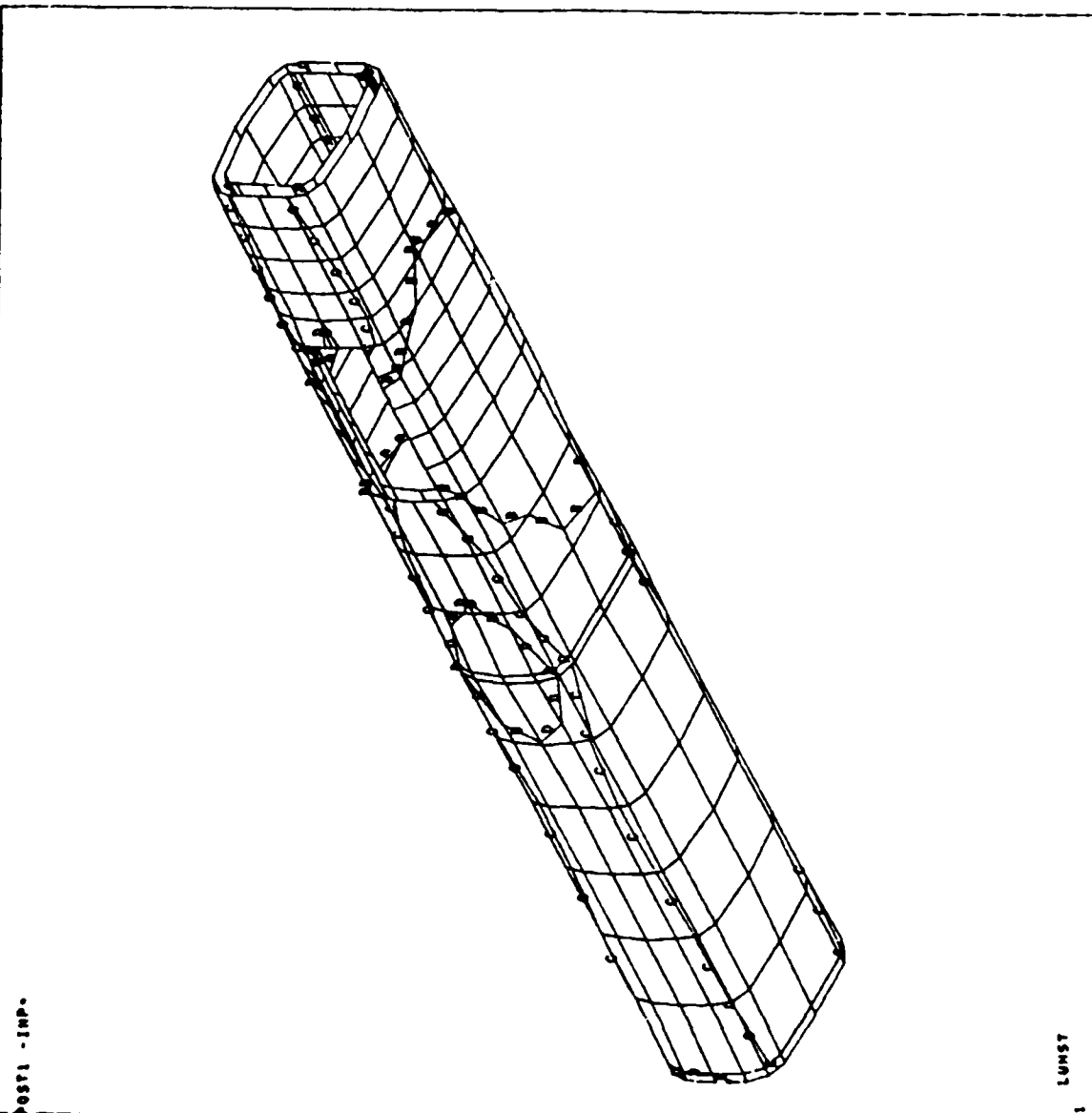
ANSYS 4.28
 JAN 12 1987
 16:16:00
 POST1 STRESS
 STEP=1
 ITER=1
 Sx7
 NU=1
 VU=1
 ZU=1
 DIST=104
 ZP=116
 HTDEM
 MX=18847
 MM=-930
 A=1388
 B=3858
 C=5954
 D=8852
 E=10550



ANSYS 4.20
 JAN 13 1987
 16:48:12
 POST1 STRESS
 STEP=1
 ITER=1
 SXT
 ZOOM
 ZU=1
 Z DIST=56.5
 Z MF=6.16
 Z VF=11.2
 Z ZF=116
 COME=40
 VERTO=1.48
 MIDDLEM
 MX=12847
 MY=-939
 A=1358
 B=3656
 C=5954
 D=8252
 E=10550

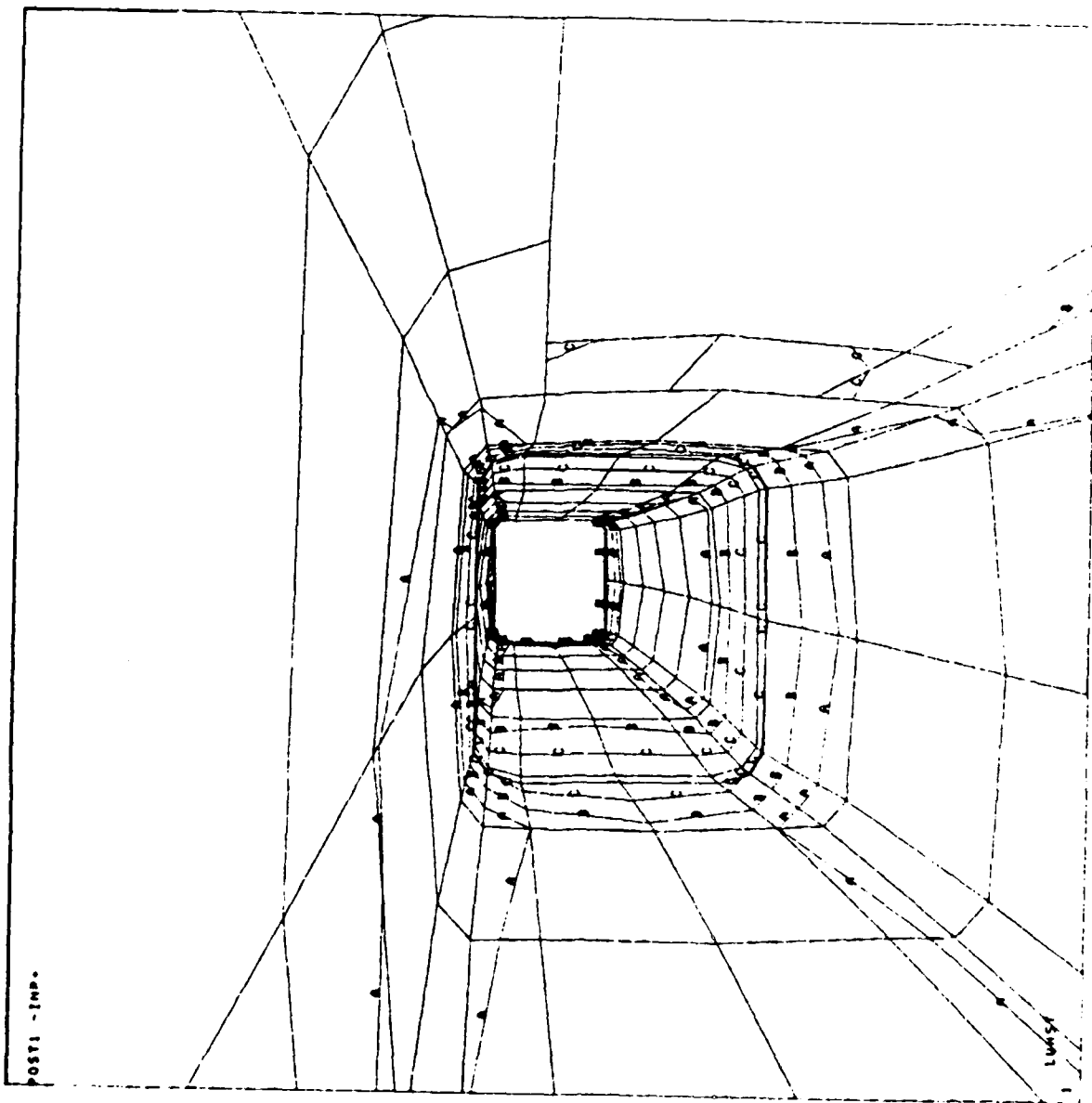


ANSYS 4.20
 JAN 13 1987
 16:18:31
 POST1 STRESS
 STEP=1
 ITER=1
 9x8
 XU=-1
 YU=-1
 ZU=1
 DIST=104
 ZF=116
 MIDDEN
 MX=13454
 MY=1251
 A=3366
 B=5384
 C=7482
 D=8428
 E=11438

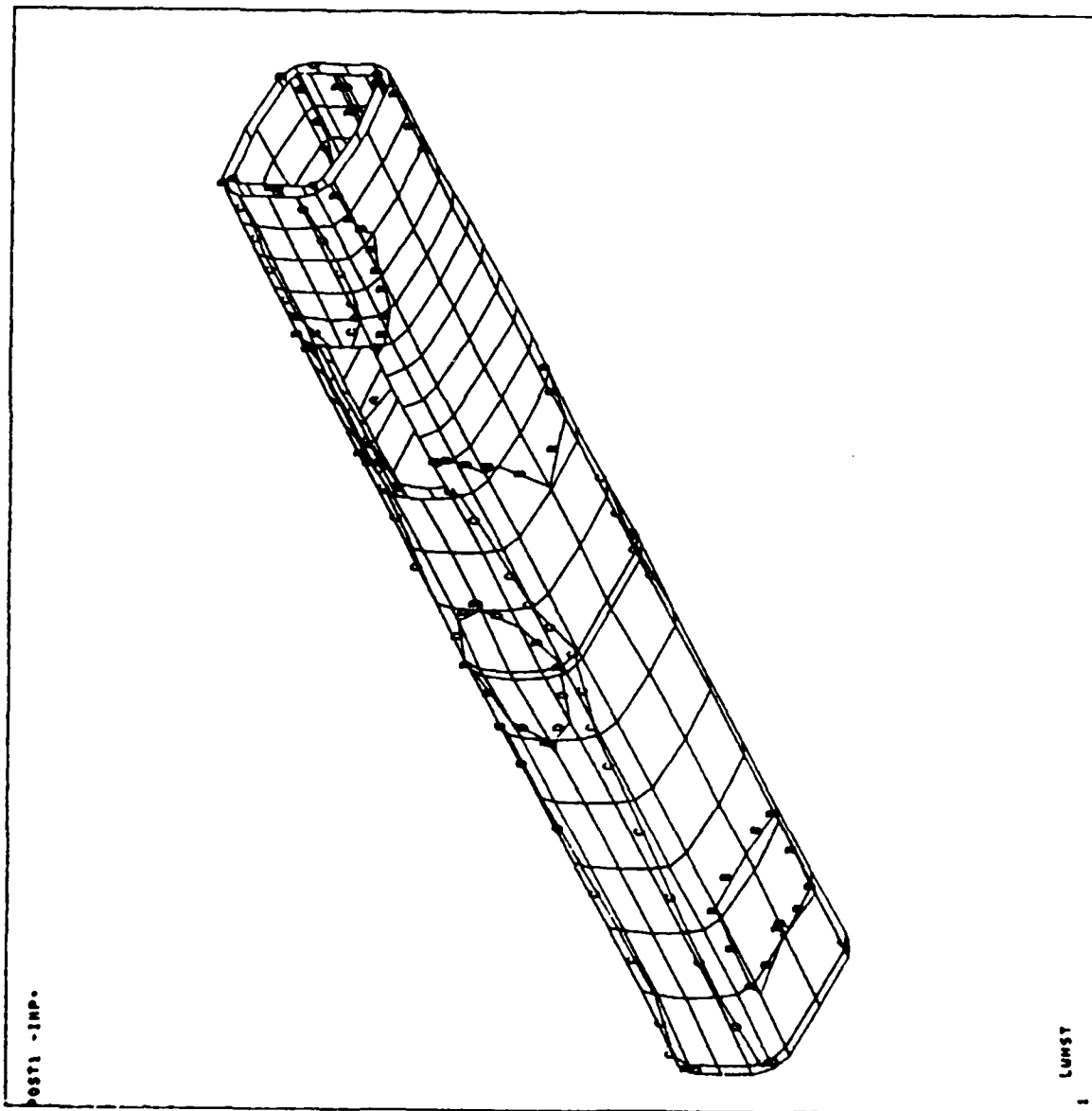


ANSYS 4.28
 JAN 13 1987
 16146145
 POST1 STRESS
 STEP=1
 ITER=1
 S48

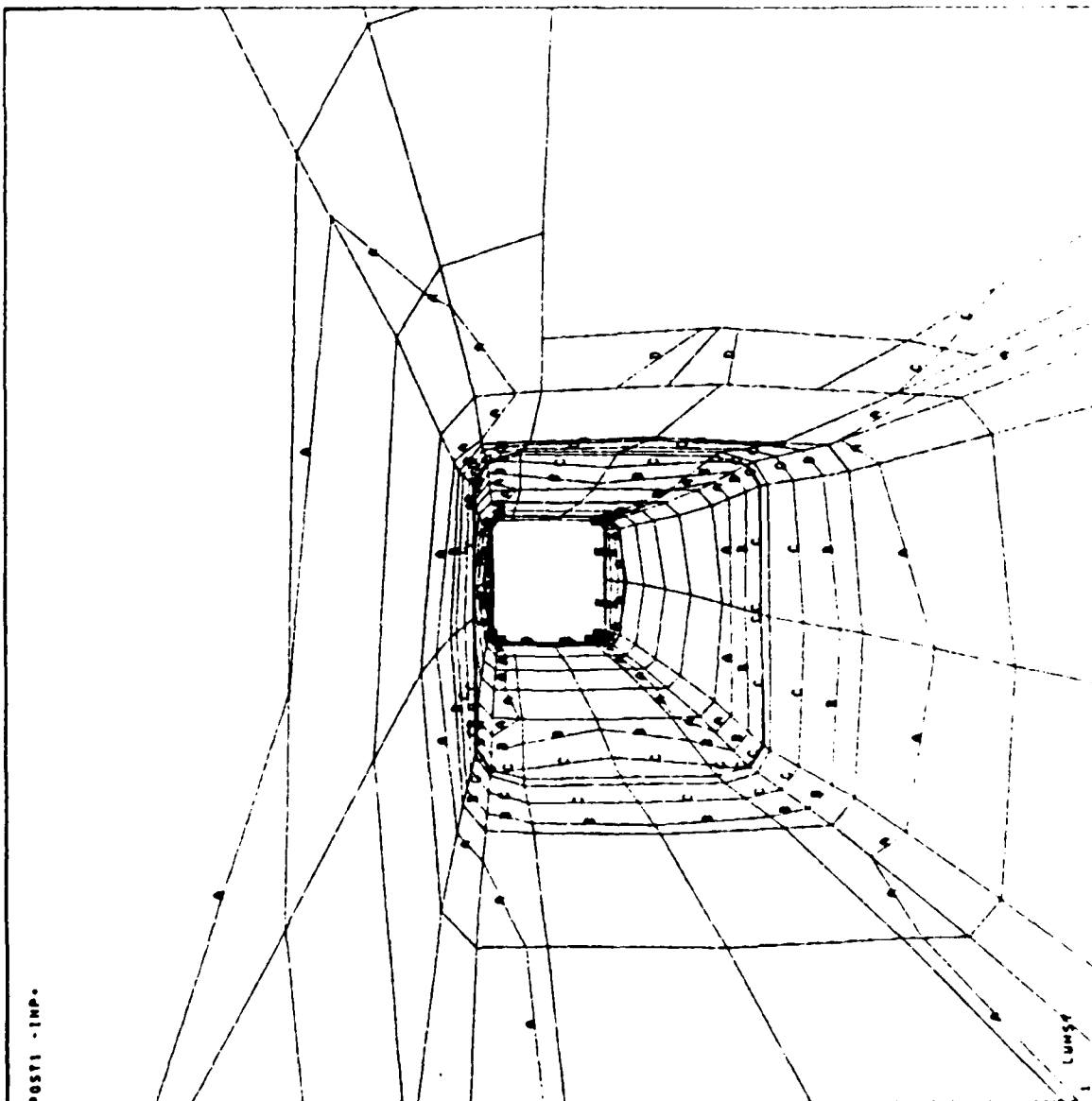
ZOOM
 ZU=1
 2 DIST=55.5
 3 KP=6.16
 4 VP=11.2
 5 ZF=116
 6 COME=40
 VRTO=1.48
 HIDDEN
 MX=13454
 MY=0
 A=3366
 B=5384
 C=7402
 D=9420
 E=11438



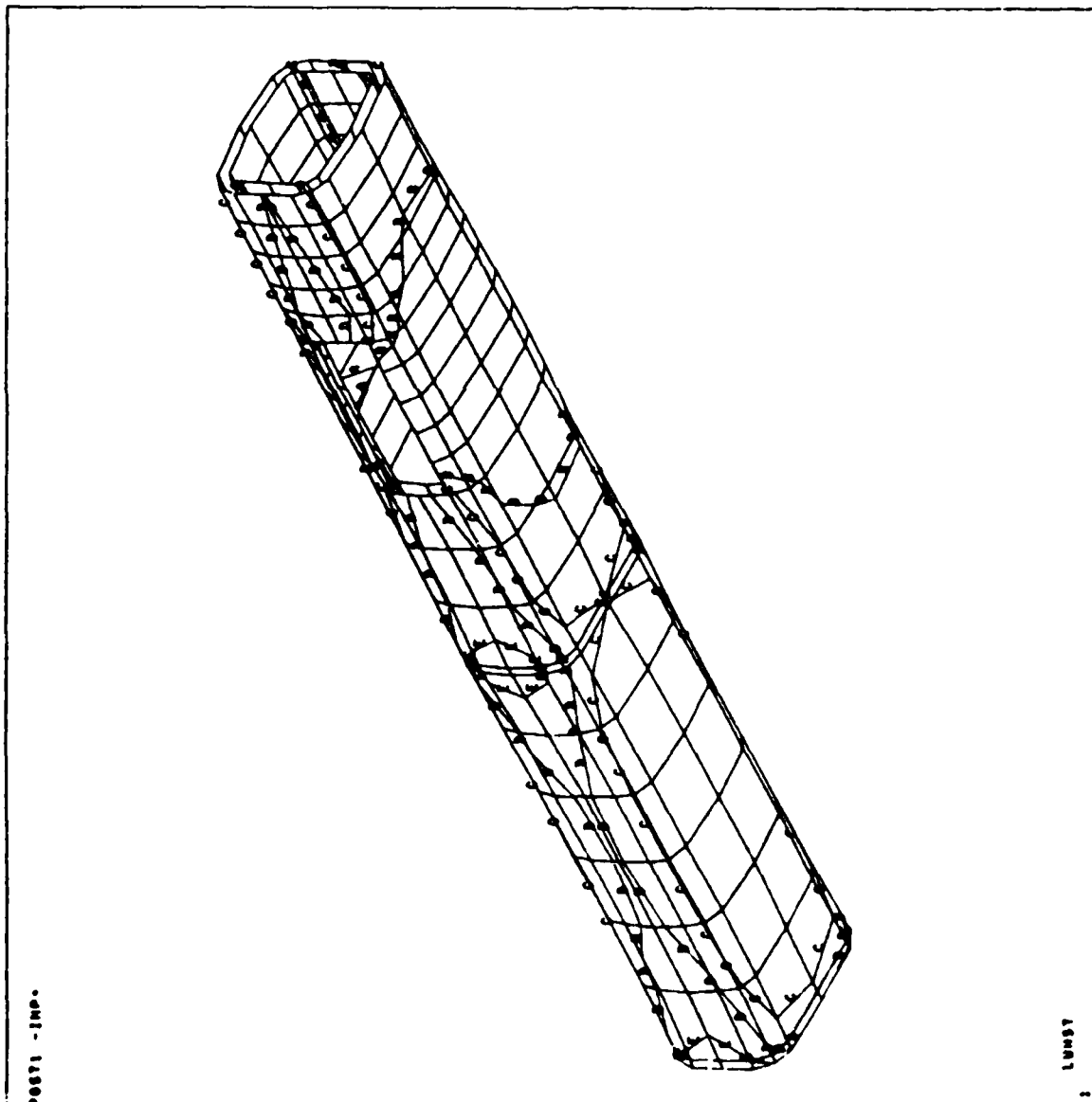
ANSYS 4.20
 JAN 13 1987
 16/20/21
 POST1 STRESS
 STEP=1
 ITER=1
 SSB
 KU=-1
 VU=-1
 ZU=1
 DIST=104
 ZF=116
 HIDDEN
 NH=13606
 NH=1346
 A=3367
 B=5305
 C=7423
 D=8451
 E=11479



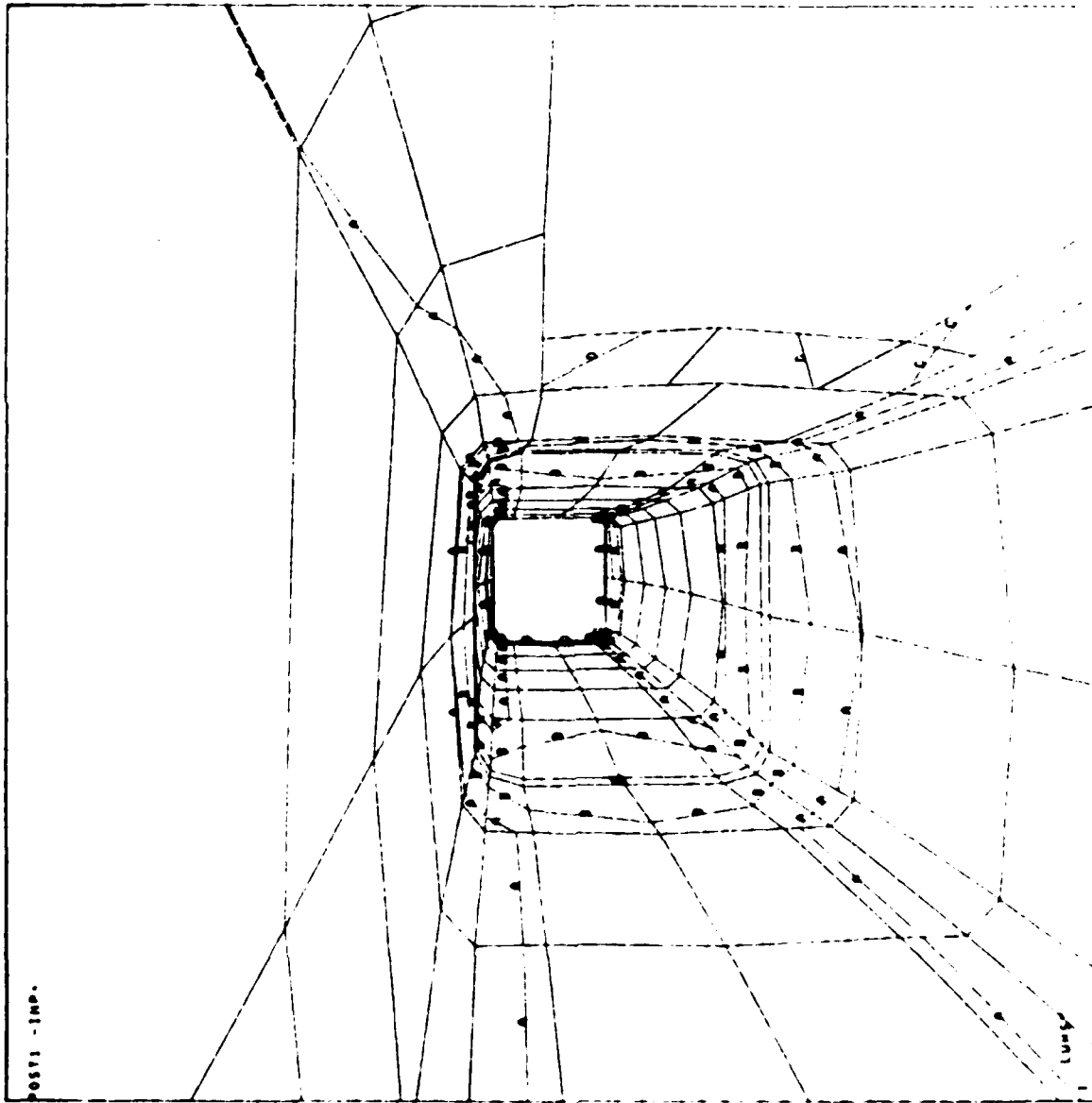
ANSYS 4.28
 JAN 13 1987
 16144127
 POST1 STRESS
 STEP=1
 ITER=1
 SLD
 ZOOM
 ZU=1
 DIST=55.6
 KF=6.16
 VF=11.2
 ZF=116
 CONE=40
 VETO=1.48
 MIDDEN
 RK=13506
 RM=9
 A=3367
 B=5395
 C=7423
 D=9451
 E=11479



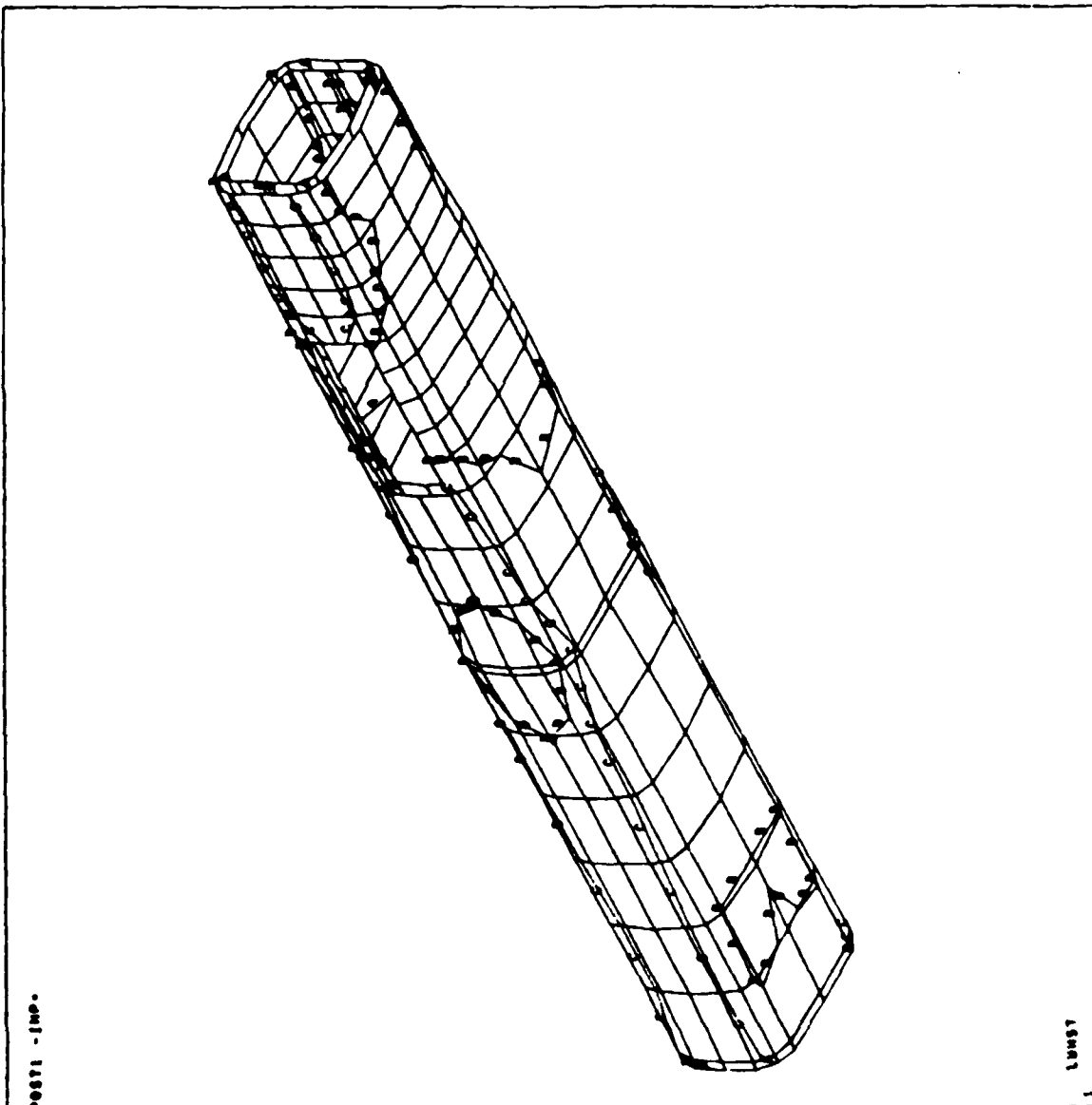
ANSYS 4.20
 JAN 13 1987
 16:22:10
 POST1, STRESS
 STEP=1
 ITER=1
 SK10
 NU=1
 VU=1
 ZU=1
 DIST=104
 ZF=118
 MIDDLEM
 MX=20036
 MY=-30.6
 A=3313
 B=6888
 C=10003
 D=13248
 E=18693



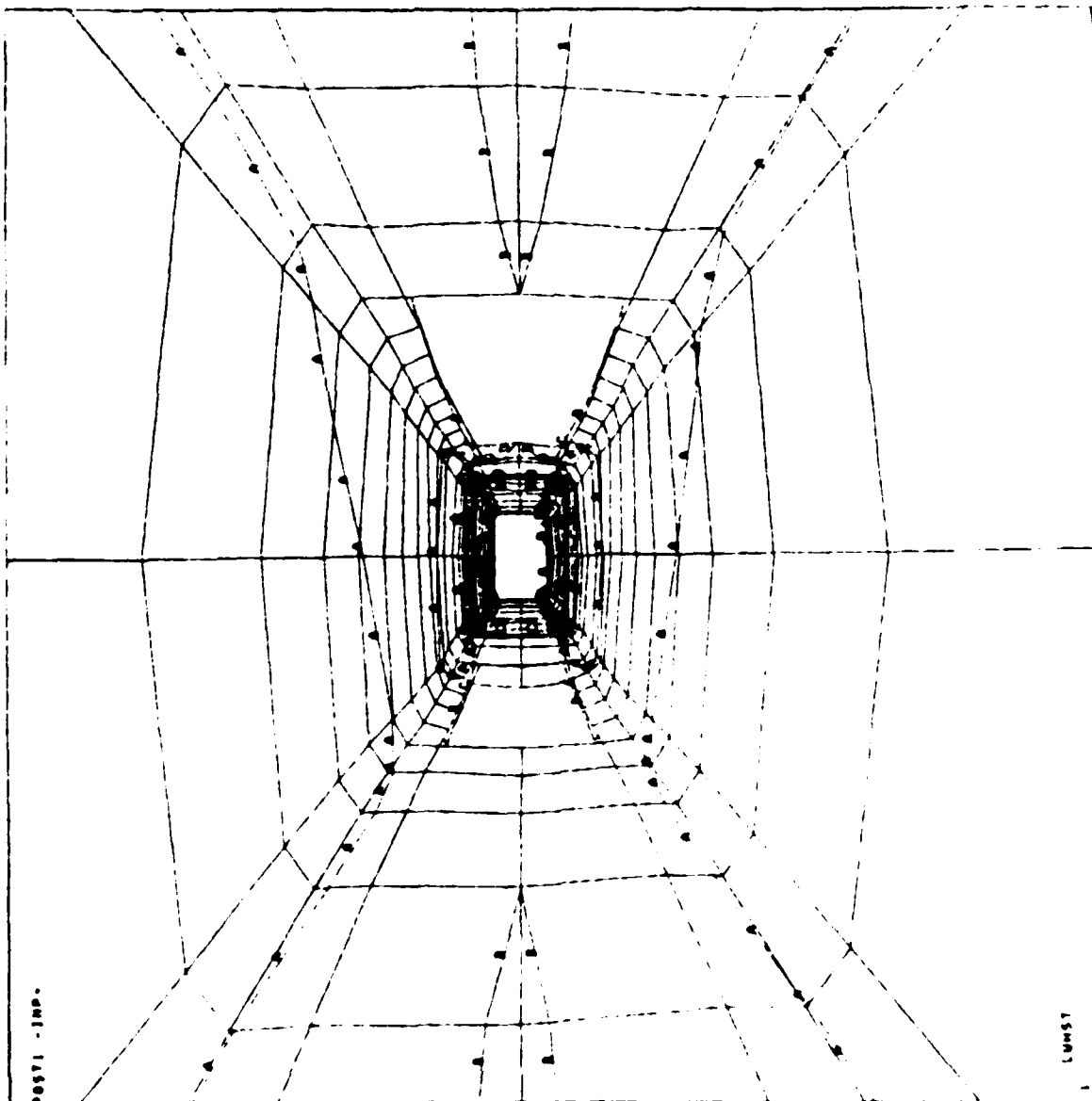
ANSYS 4.20
 JAN 13 1987
 16:42:27
 PCST1 STRESS
 STEP=1
 ITER=1
 SX10
 ZOOM
 ZU=1
 1 DIST=56.5
 1 XF=6.16
 1 VF=11.2
 1 ZF=116
 1 COME=40
 VETO=1.48
 HIDDEN
 MX=20036
 MN=0
 A=3313
 B=6658
 C=10003
 D=13348
 E=16693



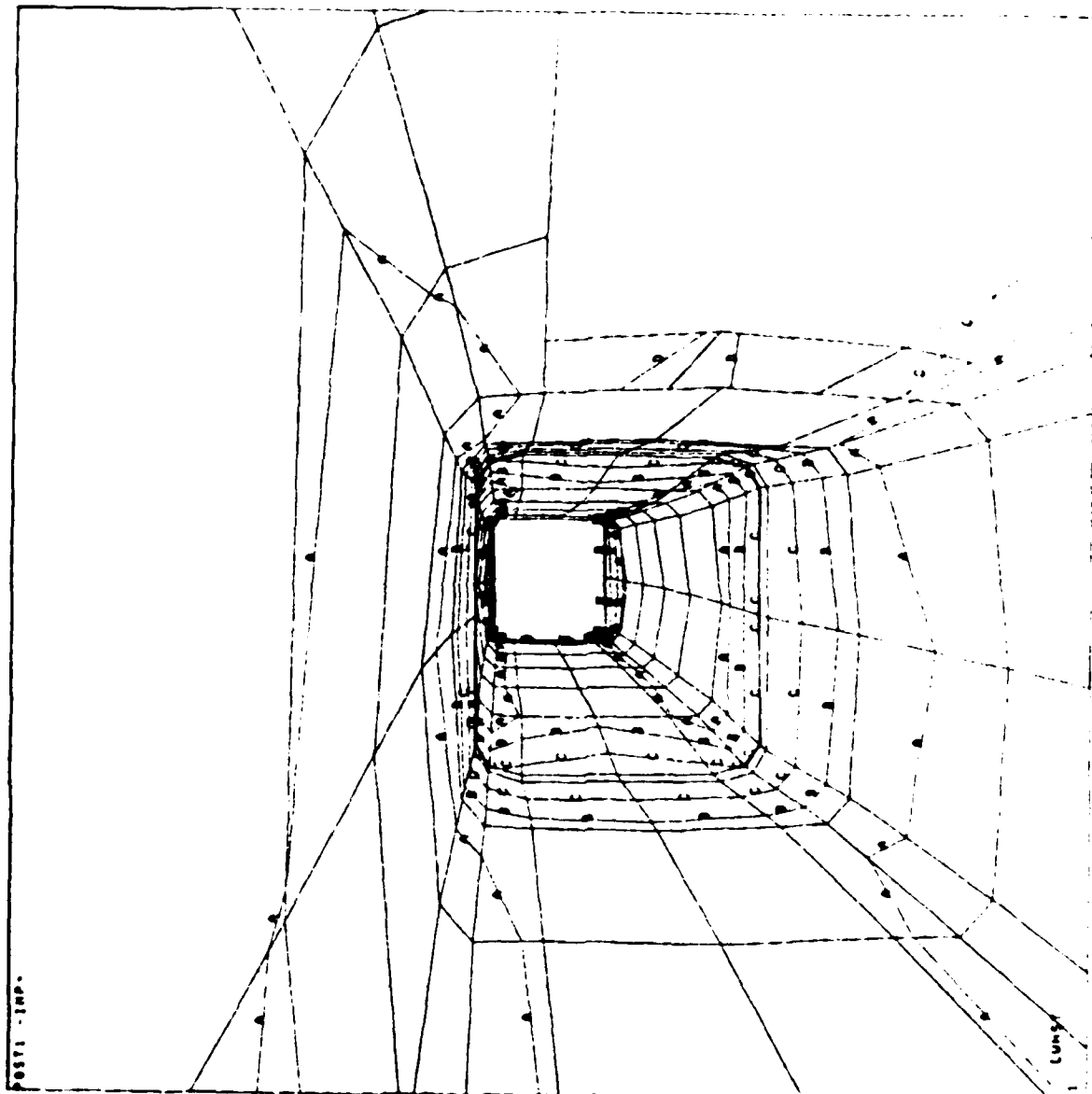
ANSYS 4.28
 JAN 13 1987
 16184143
 POST1 STRESS
 STEP=1
 1720-1
 8111
 XU=-1
 VU=-1
 ZU=-1
 8197-104
 26-116
 MIDDLE
 71-13424
 71-1200
 A-2244
 B-5280
 C-7216
 D-9352
 E-11308



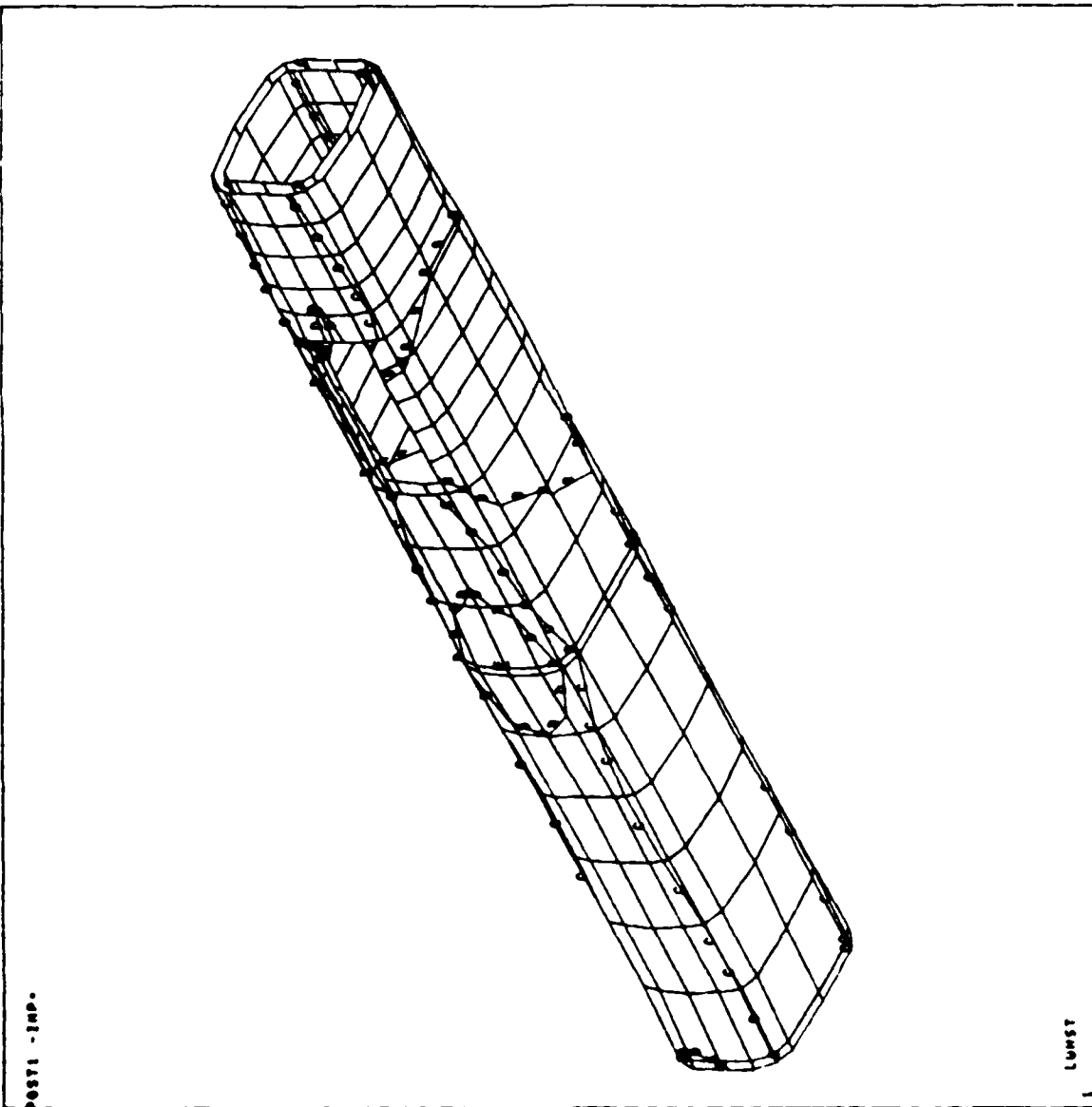
ANSYS 4.20
 JAN 13 1987
 16:39:04
 POST1 STRESS
 STEP=1
 LAYER=1
 SALL
 20:1
 B 3157-127
 1 26-116
 CONE=40
 HIDDEN
 MX=13424
 MY=0
 A=3244
 B=5200
 C=7316
 D=8352
 E=11388



ANSYS 4.20
 JAN 13 1987
 16:39:04
 POST1 STRESS
 STEP=1
 ITER=1
 SALL
 ZOOM
 ZU=1
 DIST=55.5
 KF=6.16
 VF=11.2
 ZF=116
 CONE=40
 VRTO=1.48
 MIDDLE
 RX=13424
 RM=0
 R=3244
 B=5280
 C=7316
 B=9352
 E=11380



ANSYS 4.28
 JAN 13 1987
 16:26:50
 POST1 STRESS
 STEP=1
 ITER=1
 SN12
 NU=-1
 VU=-1
 ZU=1
 B157-104
 ZF-116
 M1000
 MM-13102
 MM-1002
 A-2078
 D-5095
 C-7112
 D-9129
 E-11146



ANSYS 4.20
JAN 13 1987
161371.31

POST1 STRESS

STEP=1
ITER=1
SX12

ZU=1

E DIST=127

ZF=116

COMP=40

MIDDEL

RM=13162

RM=0

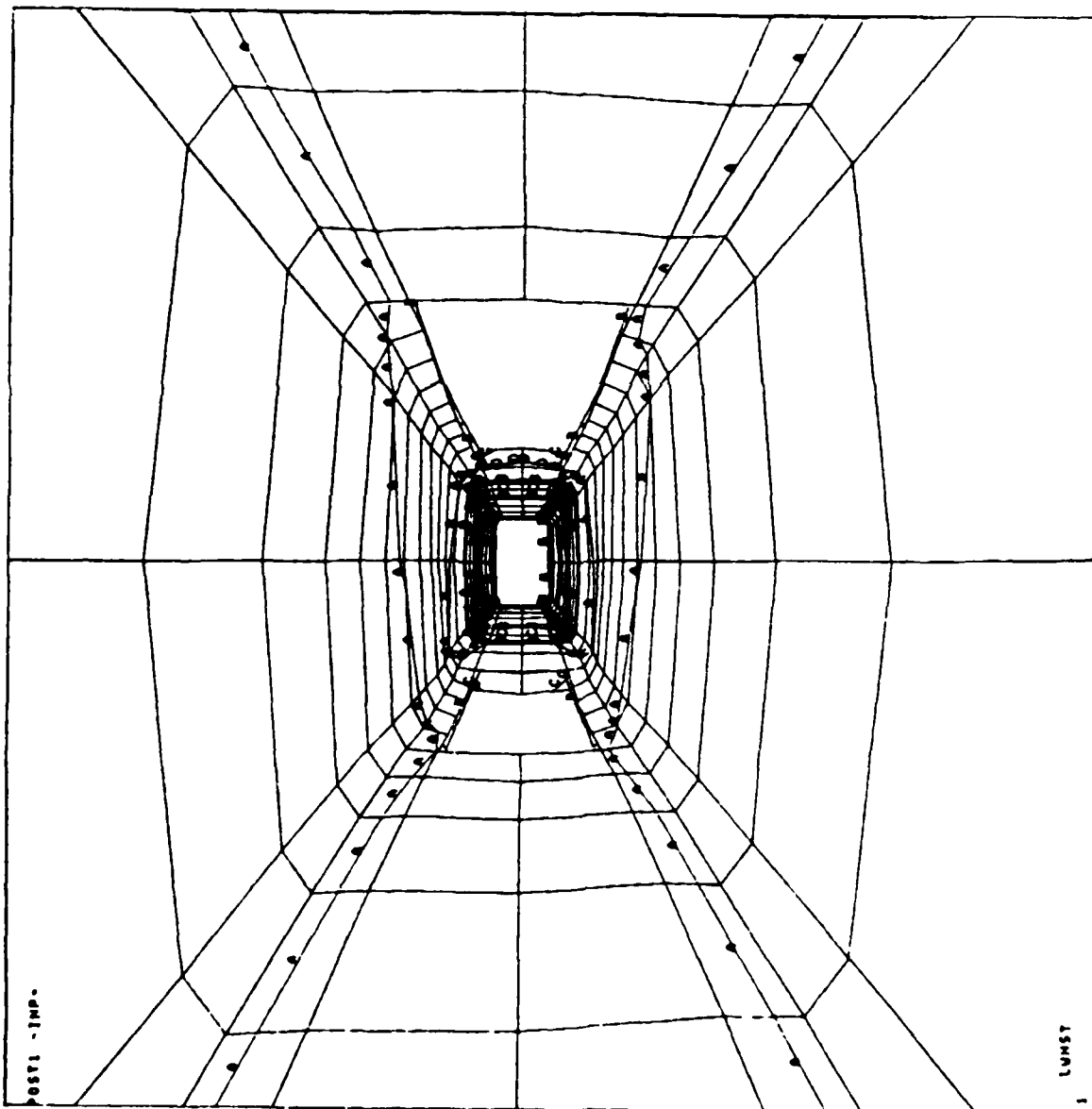
A=2078

B=5095

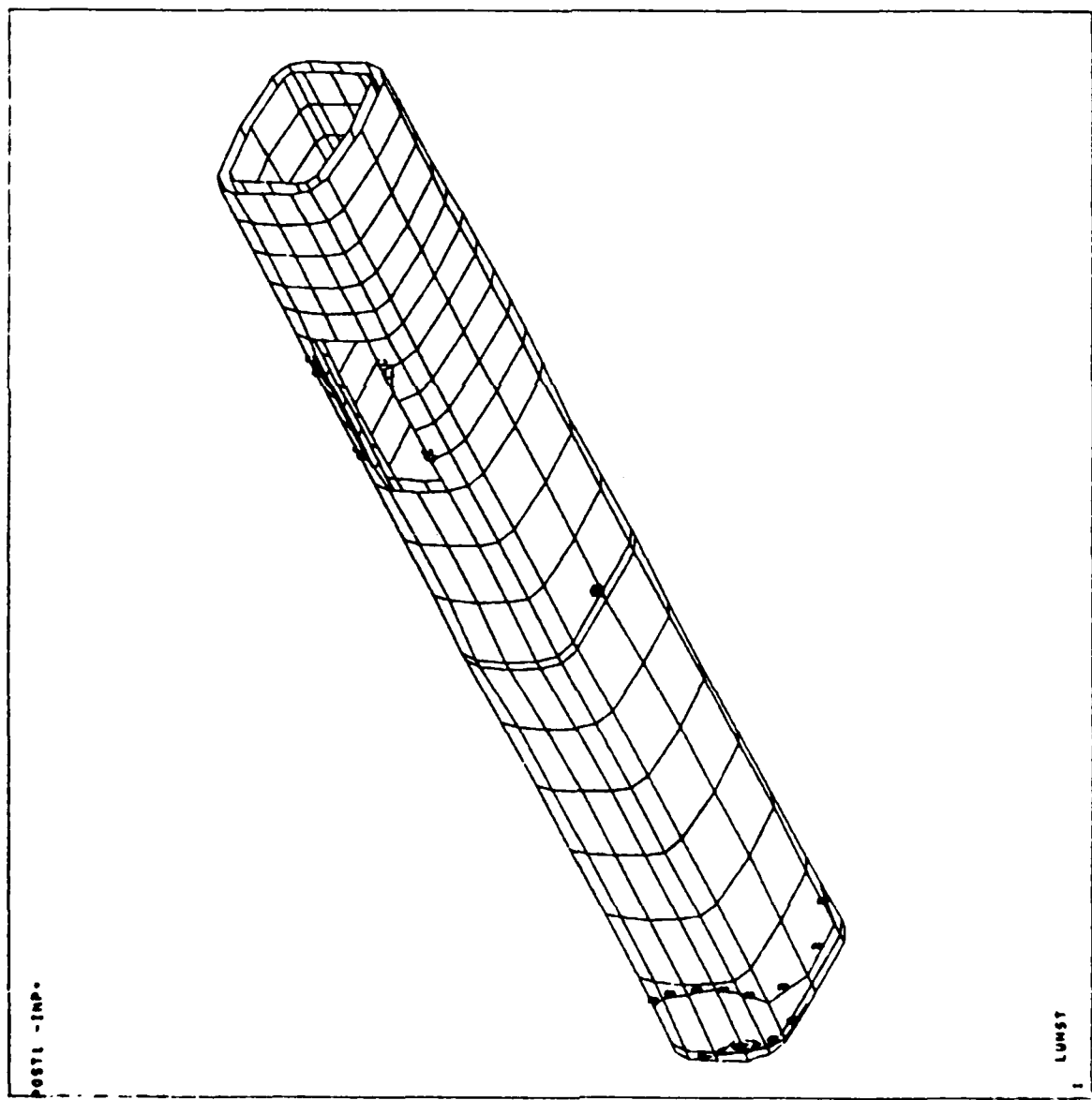
C=7112

D=9129

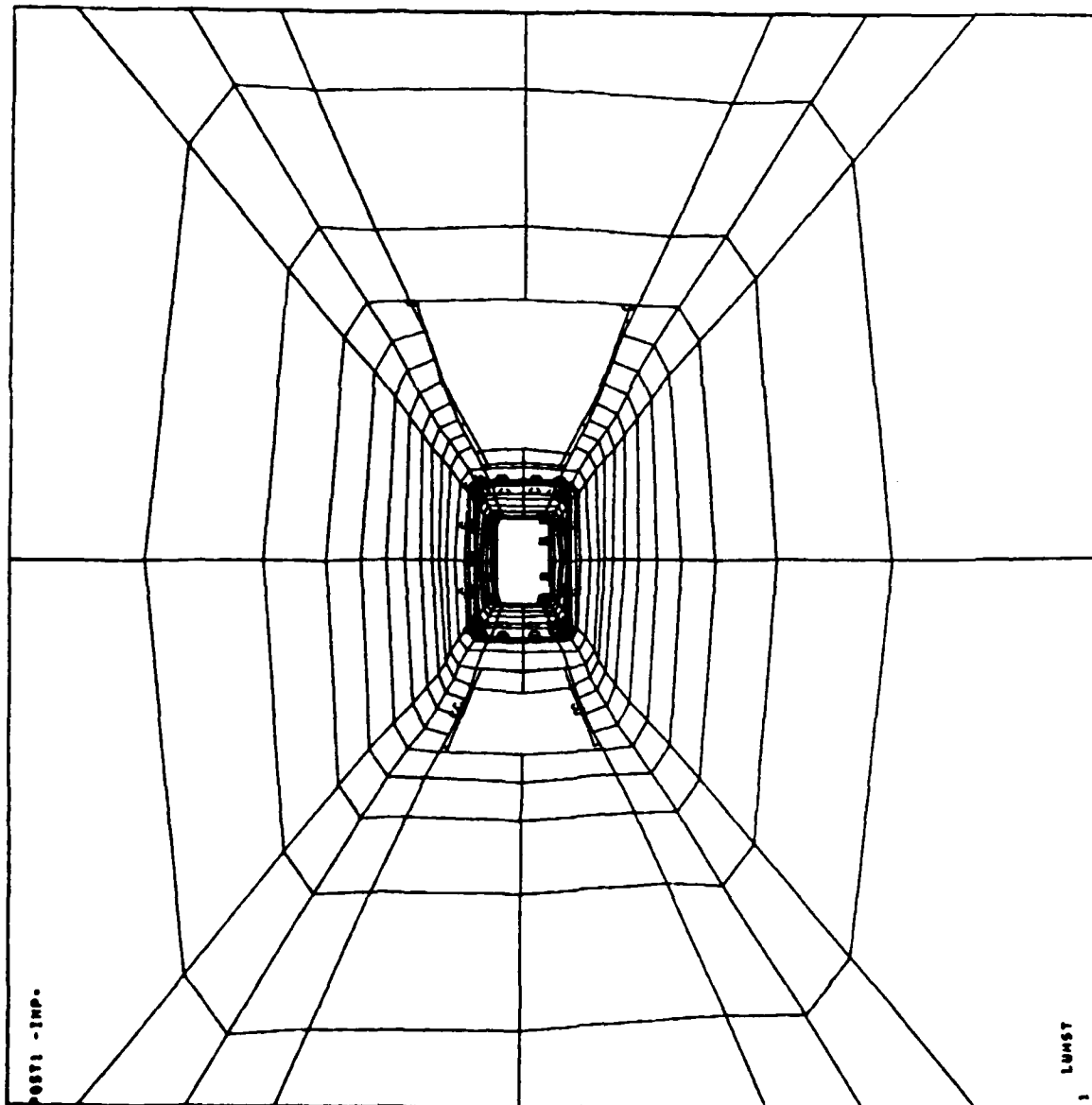
E=11146



ANSYS 4.20
 JAN 13 1987
 16130101
 POST1 STRESS
 STEP=1
 ITER=1
 SH13
 KU=-1
 VU=-1
 ZV=1
 DIST=104
 ZF=116
 MIDDEN
 MX=18549
 MY=-3040
 A=-440
 B=2151
 C=4751
 D=7351
 E=9951



ANSYS 4.20
 JAN 13 1987
 16135117
 POST1 STRESS
 STEP=1
 ITER=1
 SX13
 20-1
 8 DIST-187
 8 2F-118
 8 CONE-40
 MIDDLE
 MX-18540
 MM-3048
 A--448
 B-8151
 C-4751
 D-7351
 E-9851



D3/140

CEL MEMO: DECEMBER 22, 1986

2

FMC Central Engineering Laboratories
Santa Clara

Interoffice

To L. Libhardt**

Date Dec. 22, 1986

From C. R. Ortloff

cc E. Thuse
R. Kazares
A. Amberg
R. Rathe
E. Alexander
B. Zierwick

Subject REQUEST FOR INFORMATION: DESCRIPTION OF
THE FINITE ELEMENT MODEL(S) - LWHD PROGRAM
& FURTHER INFORMATION OF THERMAL & MOISTURE
STRESS LOADS

**one copy of original
figures only
264-269

Shown in figures 264-269** is the total system model used for dynamic studies and stress analysis. This information was requested by L. Libhardt on 19 Dec 86 for purposes of having presentation materials available for ARDEC presentations on finite element analysis by NOD staff.

The ANSYS model (3400 elements) consists of rectangular STIF 43 elements and triangular STIF 48 elements for the gimbal and platform structure (Figure 265). A separate file was made for the gimbal so that it could be added to the platform file in rotated positions (representing the 22.5° off-axis rotation cases). Appropriate density values and material properties for Ti are specified for platform, gimbal and spade.

Representations of trailing arms are made in the form of a foam core sandwich upper plate (9 Gr/Ep lamina [0/45/-45/90/0/90/-45/45/0]) over a 2-inch Rohacell core with a metal matrix truss structure (Al/SiC) and Ti bulkhead reinforcing plates (after the Concept 3 Trail Drawing, 10/29/86 and 11/12/86, D. Langerud). ANSYS STIF 53 elements were used for the composite part of the trail structure. The section properties of the hollow cross-section beams were input together with appropriate materials and geometry properties. Since I have had no update on details of this part, I am using the most current model. The trail ends (toward the platform) are connected to nodes on the platform. A STIF 4 beam representation of the cradle is next input into the model and connected to the appropriate lower gimbal mount points. This beam model is made rigid (no attempt is made to model the cradle X, Y, Z, ROTX, ROTY, ROTZ stiffnesses) and the appropriate mass distribution and rotational moment of inertia is duplicated. The CG location of the cradle is duplicated approximately also. Beam elements (STIF 4) or STIF 10 cable elements are used to model the cable attachment to the gimbal. This latter element has a bilinear stiffness matrix, i.e., the stiffness is made zero if the element goes into compression. No bending or torsional stiffness is associated with this element. For

L h m n ?

*Figures are numbered consecutively in sequent memos to avoid reference difficulties when referring to figures in different memos.

Libhardt
Memo

Dec. 22, 1986
Page 2

cases for which the STIF 4 element is used, EI is made small to duplicate the negligible bending stiffness of the cable. Reference to ANSYS Manual, V. 1, 4.10.1-4 provides a description of this element. This latter element is incorporated into later dynamic runs.

The upper and lower shaft arrangement is shown in figures 267 to 269. Beam elements (STIF 4) with appropriate geometry, inertia and materials properties are input for upper and lower shafts. Those shafts connect the gimbal to the platform. Since the STIF 4 elements have no rotational stiffness, this simulates the torque-free action of gimbal on the platform connection, i.e., no torque is transmitted through the connecting shafts between gimbal and platform.

The shafts are mounted to the appropriate gimbal and platform tabs and bearing surfaces by means of rigid beam elements so as to transmit bending and tension/compression loads. These loads are converted to shaft stresses by means of methods described in the ANSYS Manual, V. 1, 4.4.1-5. A lower connecting beam from the shaft bottom provides additional support to prevent Y translation of the lower shaft. A further beam is attached between gimbal and platform (Sketch L. Libhardt to CRO 11/15/86) to prevent relative gimbal/platform rotation about the shafts under load cases for which torque is transmitted to the gimbal. The FE models are sufficiently detailed to use as design tools for component stress analysis. Use of a smaller number of elements in a "simplified" model for this complex assembly will give erroneous global stiffness values for all components and thereby misrepresent the dynamic motion and concomitant stress states. (Note the tab detail in figure 267, for example). For metal parts, SIGE stresses are sufficient on the outer surface. For composite parts, STRESS commands up to level 3 must be issued before the SET command to store lamina stress data.

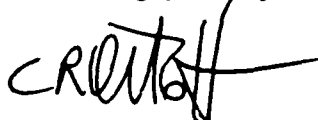
Use of /PREP6 preprocessor methodology is employed to construct the impulse force vs. time curves representing proof load recoil and firing torque loads. This .F23 file is edited to the .F27 file and run as a restart to obtain dynamic motion of the system. Output from the 30 CPU hour run consists of dynamic motion history of some 200 key Master Degree of Freedom points throughout the structure. At appropriate peaks of these curves, a stress pass can be performed to get a stress "snapshot" at any time of the entire structure (see for example, memo CRO to L. Libhardt, 12/17/86). Use of Linear Transient Dynamic Methods (KAN,5) are employed (V. 1, ANSYS Manual) to obtain a solution. Integration time steps of 0.001 sec. are used together with ramped loading between time steps to avoid numerical instabilities connected with the zero stiffness (under compression) cable elements. Use of coupling equations in all degrees of freedom

L. Libhardt
Memo

4
Dec. 22, 1986
Page 3

(except X rotation) at the cradle end-gimbal mount is made to allow for relative rotation of the cradle at these bearing points. (You may wish to rigidly pin this joint at some later time to prevent cable creep and dynamic stress effects typical of Kevlar cables under dynamic load. This will prevent resetting of the firing angles between shots and improve gun pointing accuracy). For off-axis firing, a local coordinate system is used for the combined gimbal-cradle system so as to input both firing torques and constraint/coupling equations correctly. The system is loaded with lg at all times during analysis time steps to provide a "restoring force" to the structure. The spades are pinned at their lower edge and have UY=0 constraints on the bottom horizontal surface at nodes between the vertical spade separator plates. The trail ends are not fixed. Use of UX=0 constraints on these separator plates is also made for the 22.5-0, 22.5-72 firing cases to limit side thrust travel on the spades and model the plate stress distributions correctly. Postprocessing of the computer solution is made with POST1 and POST26 routines.

Preliminary runs have been made with CMAP to estimate the thermal expansion and moisture loads on a typical [0/45/-45/90/-45/45/0] Gr/Ep composite face sheet for AS-3501/5 for 2% moisture and a temperature difference of 100°F (hot, wet conditions). Stresses as high as 15 ksi may be encountered in the 90° layers. These values are to be superimposed upon load induced stresses (Memo, CRO to J. Ries, 12/8/86). Although the CMAP results are preliminary (and will be updated by a further ANSYS cradle analysis with those effects included, they indicate additional problems for the original cradle design. It is suggested that in light of the dynamic amplification factor of 1 to 1.5 and the additional thermal expansion and moisture stresses (plus a not unreasonable safety factor of 1.5 to allow for manufacturing errors and defects plus residual curing stresses) that a redesign be considered along the lines suggested in the memo (CRO to R. Rathe, 12/8/86) if filament winding is to be retained. If a woven roving design is to be used, please forward your redesign to me at your earliest convenience so that I may modify my model accordingly and perform analyses. *



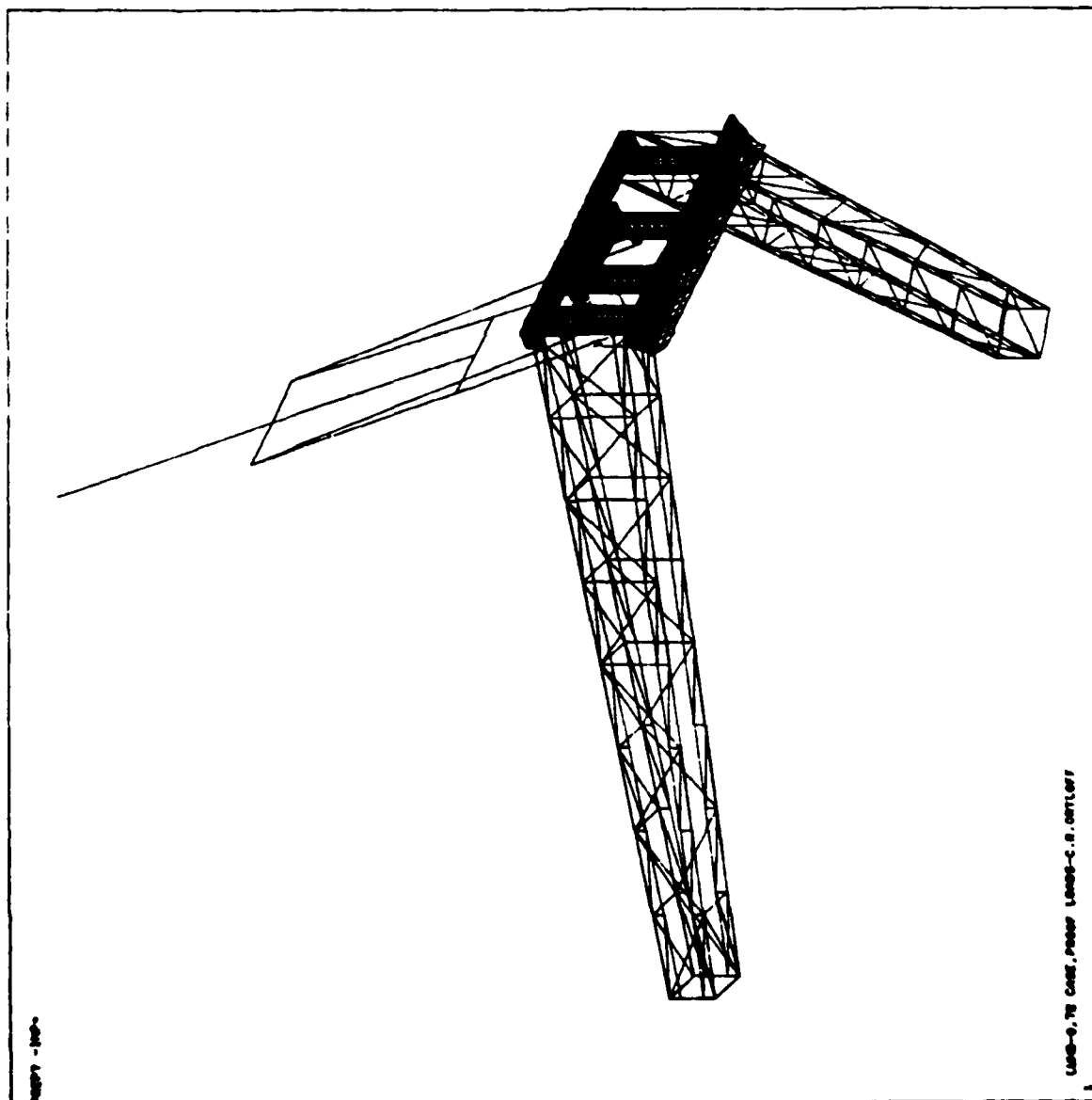
C. R. Ortloff

The 0°-72° case has been postprocessed and will be sent to Larry Libhardt on December 29.

ANALYSIS 4.20
DEC 8 1986
15118121
PREP7 ELEMENTS

200=1
201=1
202=1
203=1
204=1
205=1
206=1
207=1
208=1
209=1
210=1
211=1
212=1
213=1
214=1
215=1
216=1
217=1
218=1
219=1
220=1
221=1
222=1
223=1
224=1
225=1
226=1
227=1
228=1
229=1
230=1
231=1
232=1
233=1
234=1
235=1
236=1
237=1
238=1
239=1
240=1
241=1
242=1
243=1
244=1
245=1
246=1
247=1
248=1
249=1
250=1
251=1
252=1
253=1
254=1
255=1
256=1
257=1
258=1
259=1
260=1
261=1
262=1
263=1
264=1
265=1
266=1
267=1
268=1
269=1
270=1
271=1
272=1
273=1
274=1
275=1
276=1
277=1
278=1
279=1
280=1
281=1
282=1
283=1
284=1
285=1
286=1
287=1
288=1
289=1
290=1
291=1
292=1
293=1
294=1
295=1
296=1
297=1
298=1
299=1
300=1

0, 72° CASE



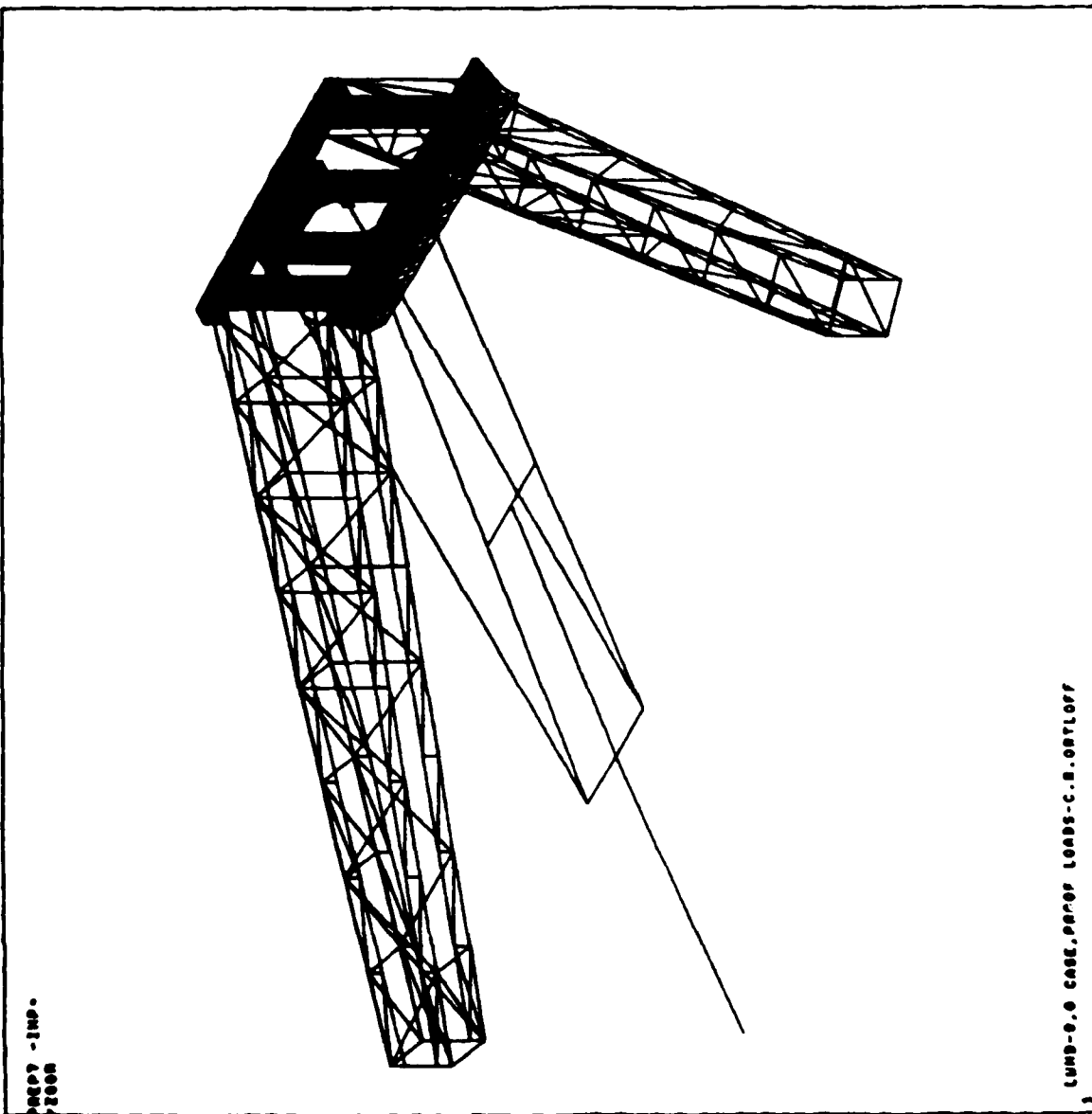
1000-1000

1000-1000 CASE, PREP7 LOADS-C.B. OUTLIER

ANSYS 4.20
 DEC 5 1988
 10120104
 PREP7 ELEMENTS

20--1
 20--1
 20--1
 20--1
 20--1
 20--1
 20--1

0°-0° CASE



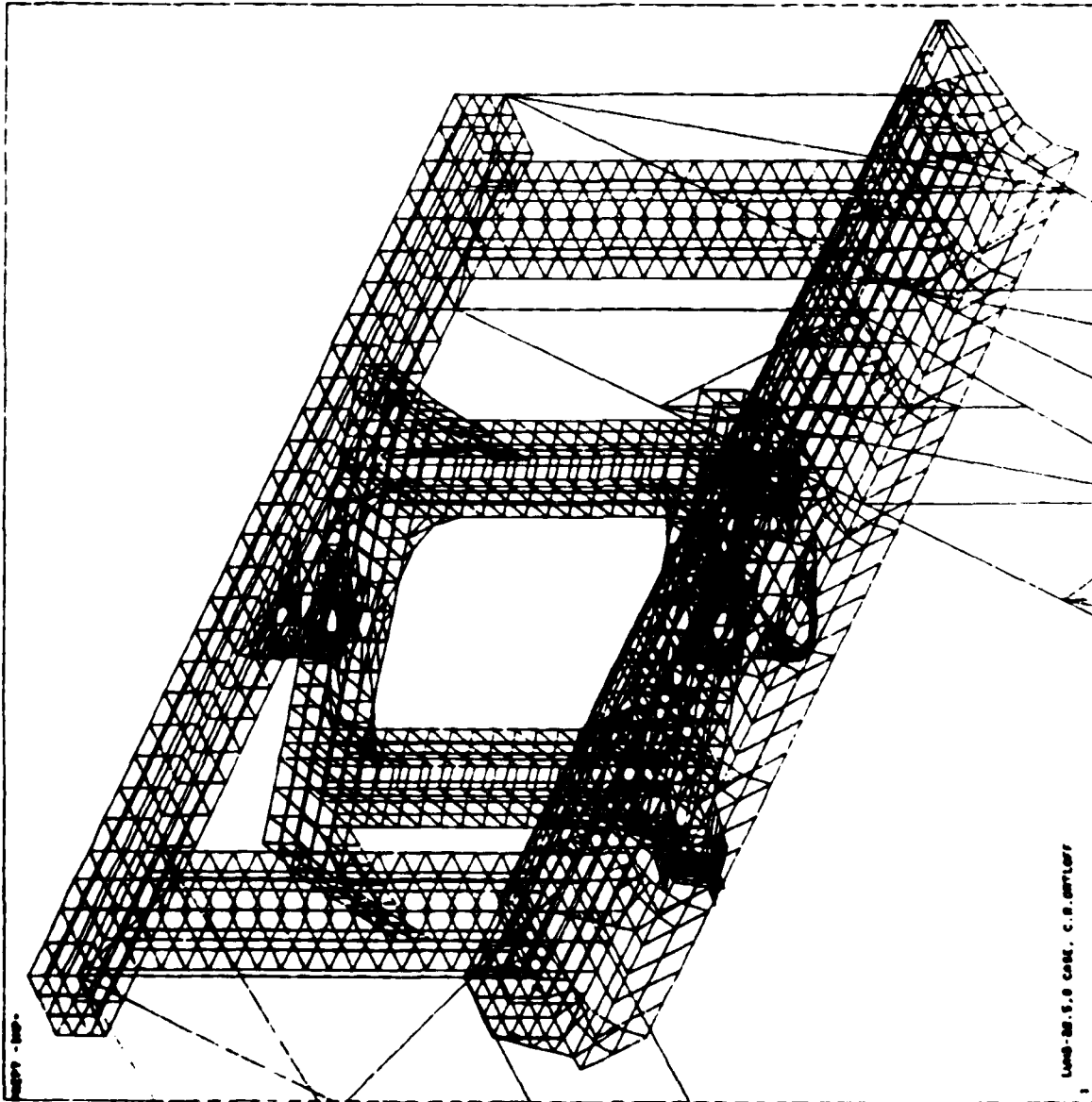
2002
 2002

1 LUND-0.0 CASE, PREP7 LOADS-C.D.ORTLOFF

SECURITY CODE
01-03-0
NOV 11 1961
NO 0 04000

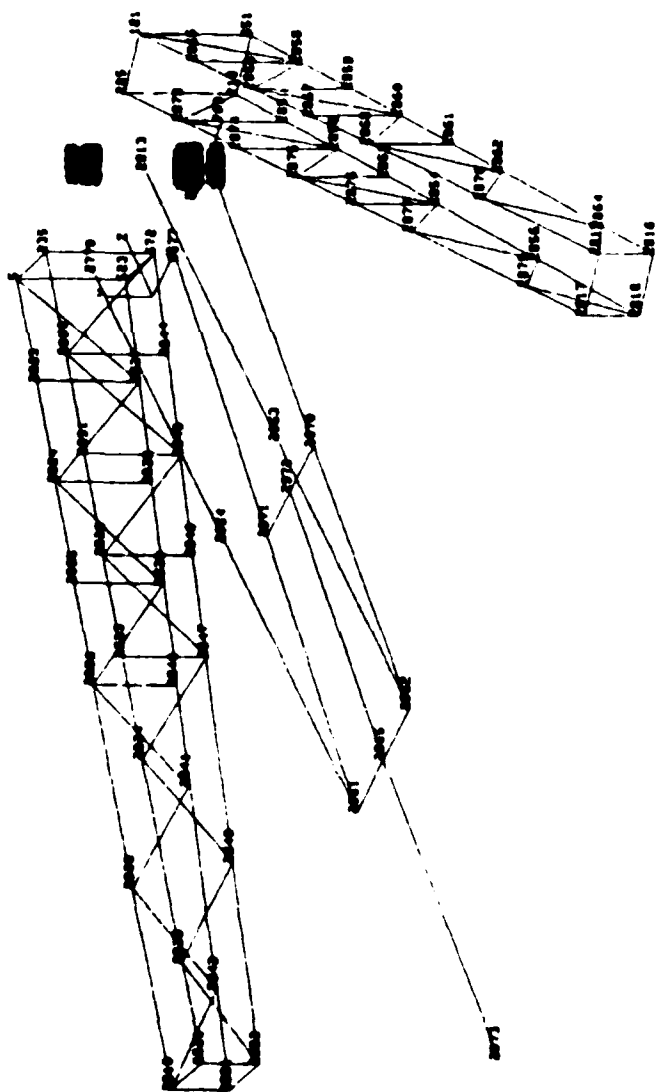
2004
WJ-1
WJ-1
ZU-1
B187-55.3
W-106
W-78.8
ZP-47.4
MPTG-1.10

ROTATED GIMBAL
ON PLATFORM
22.5° ROTATION

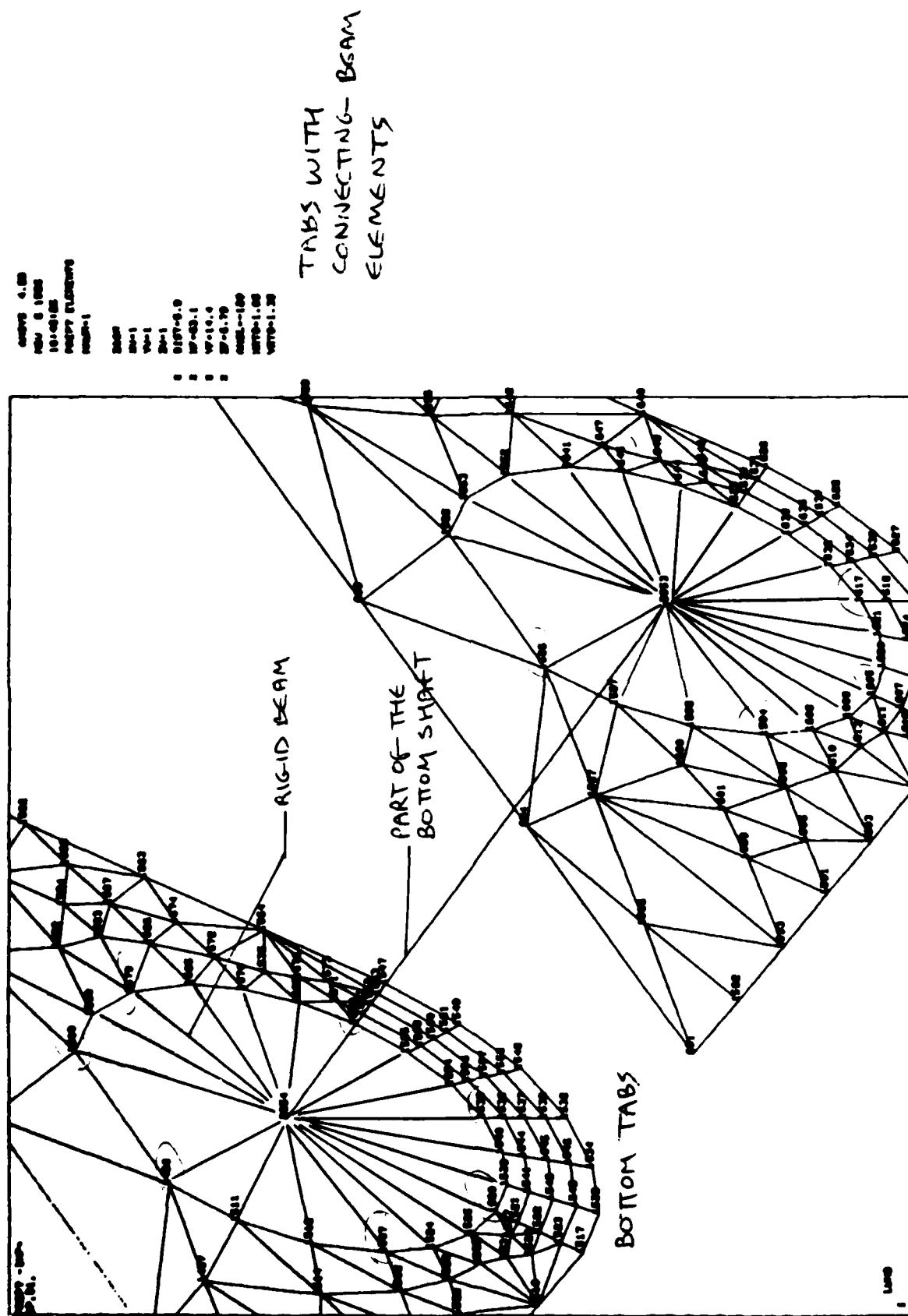


11

BEAM REPRESENTATIONS
OF CRADLE AND TRAILS
(TRAILS CONTAIN
COMPOSITE STIFF
ELEMENTS ON TOP FACE)
 $0^{\circ} - 0^{\circ}$ CASE



100-0,0 Call, Power 1000-C. B. 007100



10000 4.00
 10000 7.1000
 10000 10.2000
 10000 13.3000
 10000 16.4000
 10000 19.5000
 10000 22.6000
 10000 25.7000
 10000 28.8000
 10000 31.9000
 10000 35.0000
 10000 38.1000
 10000 41.2000
 10000 44.3000
 10000 47.4000
 10000 50.5000
 10000 53.6000
 10000 56.7000
 10000 59.8000
 10000 62.9000
 10000 66.0000
 10000 69.1000
 10000 72.2000
 10000 75.3000
 10000 78.4000
 10000 81.5000
 10000 84.6000
 10000 87.7000
 10000 90.8000
 10000 93.9000
 10000 97.0000
 10000 100.1000
 10000 103.2000
 10000 106.3000
 10000 109.4000
 10000 112.5000
 10000 115.6000
 10000 118.7000
 10000 121.8000
 10000 124.9000
 10000 128.0000
 10000 131.1000
 10000 134.2000
 10000 137.3000
 10000 140.4000
 10000 143.5000
 10000 146.6000
 10000 149.7000
 10000 152.8000
 10000 155.9000
 10000 159.0000
 10000 162.1000
 10000 165.2000
 10000 168.3000
 10000 171.4000
 10000 174.5000
 10000 177.6000
 10000 180.7000
 10000 183.8000
 10000 186.9000
 10000 190.0000
 10000 193.1000
 10000 196.2000
 10000 199.3000
 10000 202.4000
 10000 205.5000
 10000 208.6000
 10000 211.7000
 10000 214.8000
 10000 217.9000
 10000 221.0000
 10000 224.1000
 10000 227.2000
 10000 230.3000
 10000 233.4000
 10000 236.5000
 10000 239.6000
 10000 242.7000
 10000 245.8000
 10000 248.9000
 10000 252.0000
 10000 255.1000
 10000 258.2000
 10000 261.3000
 10000 264.4000
 10000 267.5000
 10000 270.6000
 10000 273.7000
 10000 276.8000
 10000 279.9000
 10000 283.0000
 10000 286.1000
 10000 289.2000
 10000 292.3000
 10000 295.4000
 10000 298.5000
 10000 301.6000
 10000 304.7000
 10000 307.8000
 10000 310.9000
 10000 314.0000
 10000 317.1000
 10000 320.2000
 10000 323.3000
 10000 326.4000
 10000 329.5000
 10000 332.6000
 10000 335.7000
 10000 338.8000
 10000 341.9000
 10000 345.0000
 10000 348.1000
 10000 351.2000
 10000 354.3000
 10000 357.4000
 10000 360.5000
 10000 363.6000
 10000 366.7000
 10000 369.8000
 10000 372.9000
 10000 376.0000
 10000 379.1000
 10000 382.2000
 10000 385.3000
 10000 388.4000
 10000 391.5000
 10000 394.6000
 10000 397.7000
 10000 400.8000
 10000 403.9000
 10000 407.0000
 10000 410.1000
 10000 413.2000
 10000 416.3000
 10000 419.4000
 10000 422.5000
 10000 425.6000
 10000 428.7000
 10000 431.8000
 10000 434.9000
 10000 438.0000
 10000 441.1000
 10000 444.2000
 10000 447.3000
 10000 450.4000
 10000 453.5000
 10000 456.6000
 10000 459.7000
 10000 462.8000
 10000 465.9000
 10000 469.0000
 10000 472.1000
 10000 475.2000
 10000 478.3000
 10000 481.4000
 10000 484.5000
 10000 487.6000
 10000 490.7000
 10000 493.8000
 10000 496.9000
 10000 500.0000
 10000 503.1000
 10000 506.2000
 10000 509.3000
 10000 512.4000
 10000 515.5000
 10000 518.6000
 10000 521.7000
 10000 524.8000
 10000 527.9000
 10000 531.0000
 10000 534.1000
 10000 537.2000
 10000 540.3000
 10000 543.4000
 10000 546.5000
 10000 549.6000
 10000 552.7000
 10000 555.8000
 10000 558.9000
 10000 562.0000
 10000 565.1000
 10000 568.2000
 10000 571.3000
 10000 574.4000
 10000 577.5000
 10000 580.6000
 10000 583.7000
 10000 586.8000
 10000 589.9000
 10000 593.0000
 10000 596.1000
 10000 599.2000
 10000 602.3000
 10000 605.4000
 10000 608.5000
 10000 611.6000
 10000 614.7000
 10000 617.8000
 10000 620.9000
 10000 624.0000
 10000 627.1000
 10000 630.2000
 10000 633.3000
 10000 636.4000
 10000 639.5000
 10000 642.6000
 10000 645.7000
 10000 648.8000
 10000 651.9000
 10000 655.0000
 10000 658.1000
 10000 661.2000
 10000 664.3000
 10000 667.4000
 10000 670.5000
 10000 673.6000
 10000 676.7000
 10000 679.8000
 10000 682.9000
 10000 686.0000
 10000 689.1000
 10000 692.2000
 10000 695.3000
 10000 698.4000
 10000 701.5000
 10000 704.6000
 10000 707.7000
 10000 710.8000
 10000 713.9000
 10000 717.0000
 10000 720.1000
 10000 723.2000
 10000 726.3000
 10000 729.4000
 10000 732.5000
 10000 735.6000
 10000 738.7000
 10000 741.8000
 10000 744.9000
 10000 748.0000
 10000 751.1000
 10000 754.2000
 10000 757.3000
 10000 760.4000
 10000 763.5000
 10000 766.6000
 10000 769.7000
 10000 772.8000
 10000 775.9000
 10000 779.0000
 10000 782.1000
 10000 785.2000
 10000 788.3000
 10000 791.4000
 10000 794.5000
 10000 797.6000
 10000 800.7000
 10000 803.8000
 10000 806.9000
 10000 810.0000
 10000 813.1000
 10000 816.2000
 10000 819.3000
 10000 822.4000
 10000 825.5000
 10000 828.6000
 10000 831.7000
 10000 834.8000
 10000 837.9000
 10000 841.0000
 10000 844.1000
 10000 847.2000
 10000 850.3000
 10000 853.4000
 10000 856.5000
 10000 859.6000
 10000 862.7000
 10000 865.8000
 10000 868.9000
 10000 872.0000
 10000 875.1000
 10000 878.2000
 10000 881.3000
 10000 884.4000
 10000 887.5000
 10000 890.6000
 10000 893.7000
 10000 896.8000
 10000 899.9000
 10000 903.0000
 10000 906.1000
 10000 909.2000
 10000 912.3000
 10000 915.4000
 10000 918.5000
 10000 921.6000
 10000 924.7000
 10000 927.8000
 10000 930.9000
 10000 934.0000
 10000 937.1000
 10000 940.2000
 10000 943.3000
 10000 946.4000
 10000 949.5000
 10000 952.6000
 10000 955.7000
 10000 958.8000
 10000 961.9000
 10000 965.0000
 10000 968.1000
 10000 971.2000
 10000 974.3000
 10000 977.4000
 10000 980.5000
 10000 983.6000
 10000 986.7000
 10000 989.8000
 10000 992.9000
 10000 996.0000
 10000 999.1000
 10000 1002.2000
 10000 1005.3000
 10000 1008.4000
 10000 1011.5000
 10000 1014.6000
 10000 1017.7000
 10000 1020.8000
 10000 1023.9000
 10000 1027.0000
 10000 1030.1000
 10000 1033.2000
 10000 1036.3000
 10000 1039.4000
 10000 1042.5000
 10000 1045.6000
 10000 1048.7000
 10000 1051.8000
 10000 1054.9000
 10000 1058.0000
 10000 1061.1000
 10000 1064.2000
 10000 1067.3000
 10000 1070.4000
 10000 1073.5000
 10000 1076.6000
 10000 1079.7000
 10000 1082.8000
 10000 1085.9000
 10000 1089.0000
 10000 1092.1000
 10000 1095.2000
 10000 1098.3000
 10000 1101.4000
 10000 1104.5000
 10000 1107.6000
 10000 1110.7000
 10000 1113.8000
 10000 1116.9000
 10000 1120.0000
 10000 1123.1000
 10000 1126.2000
 10000 1129.3000
 10000 1132.4000
 10000 1135.5000
 10000 1138.6000
 10000 1141.7000
 10000 1144.8000
 10000 1147.9000
 10000 1151.0000
 10000 1154.1000
 10000 1157.2000
 10000 1160.3000
 10000 1163.4000
 10000 1166.5000
 10000 1169.6000
 10000 1172.7000
 10000 1175.8000
 10000 1178.9000
 10000 1182.0000
 10000 1185.1000
 10000 1188.2000
 10000 1191.3000
 10000 1194.4000
 10000 1197.5000
 10000 1200.6000
 10000 1203.7000
 10000 1206.8000
 10000 1209.9000
 10000 1213.0000
 10000 1216.1000
 10000 1219.2000
 10000 1222.3000
 10000 1225.4000
 10000 1228.5000
 10000 1231.6000
 10000 1234.7000
 10000 1237.8000
 10000 1240.9000
 10000 1244.0000
 10000 1247.1000
 10000 1250.2000
 10000 1253.3000
 10000 1256.4000
 10000 1259.5000
 10000 1262.6000
 10000 1265.7000
 10000 1268.8000
 10000 1271.9000
 10000 1275.0000
 10000 1278.1000
 10000 1281.2000
 10000 1284.3000
 10000 1287.4000
 10000 1290.5000
 10000 1293.6000
 10000 1296.7000
 10000 1299.8000
 10000 1302.9000
 10000 1306.0000
 10000 1309.1000
 10000 1312.2000
 10000 1315.3000
 10000 1318.4000
 10000 1321.5000
 10000 1324.6000
 10000 1327.7000
 10000 1330.8000
 10000 1333.9000
 10000 1337.0000
 10000 1340.1000
 10000 1343.2000
 10000 1346.3000
 10000 1349.4000
 10000 1352.5000
 10000 1355.6000
 10000 1358.7000
 10000 1361.8000
 10000 1364.9000
 10000 1368.0000
 10000 1371.1000
 10000 1374.2000
 10000 1377.3000
 10000 1380.4000
 10000 1383.5000
 10000 1386.6000
 10000 1389.7000
 10000 1392.8000
 10000 1395.9000
 10000 1399.0000
 10000 1402.1000
 10000 1405.2000
 10000 1408.3000
 10000 1411.4000
 10000 1414.5000
 10000 1417.6000
 10000 1420.7000
 10000 1423.8000
 10000 1426.9000
 10000 1430.0000
 10000 1433.1000
 10000 1436.2000
 10000 1439.3000
 10000 1442.4000
 10000 1445.5000
 10000 1448.6000
 10000 1451.7000
 10000 1454.8000
 10000 1457.9000
 10000 1461.0000
 10000 1464.1000
 10000 1467.2000
 10000 1470.3000
 10000 1473.4000
 10000 1476.5000
 10000 1479.6000
 10000 1482.7000
 10000 1485.8000
 10000 1488.9000
 10000 1492.0000
 10000 1495.1000
 10000 1498.2000
 10000 1501.3000
 10000 1504.4000
 10000 1507.5000
 10000 1510.6000
 10000 1513.7000
 10000 1516.8000
 10000 1519.9000
 10000 1523.0000
 10000 1526.1000
 10000 1529.2000
 10000 1532.3000
 10000 1535.4000
 10000 1538.5000
 10000 1541.6000
 10000 1544.7000
 10000 1547.8000
 10000 1550.9000
 10000 1554.0000
 10000 1557.1000
 10000 1560.2000
 10000 1563.3000
 10000 1566.4000
 10000 1569.5000
 10000 1572.6000
 10000 1575.7000
 10000 1578.8000
 10000 1581.9000
 10000 1585.0000
 10000 1588.1000
 10000 1591.2000
 10000 1594.3000
 10000 1597.4000
 10000 1600.5000
 10000 1603.6000
 10000 1606.7000
 10000 1609.8000
 10000 1612.9000
 10000 1616.0000
 10000 1619.1000
 10000 1622.2000
 10000 1625.3000
 10000 1628.4000
 10000 1631.5000
 10000 1634.6000
 10000 1637.7000
 10000 1640.8000
 10000 1643.9000
 10000 1647.0000
 10000 1650.1000
 10000 1653.2000
 10000 1656.3000
 10000 1659.4000
 10000 1662.5000
 10000 1665.6000
 10000 1668.7000
 10000 1671.8000
 10000 1674.9000
 10000 1678.0000
 10000 1681.1000
 10000 1684.2000
 10000 1687.3000
 10000 1690.4000
 10000 1693.5000
 10000 1696.6000
 10000 1699.7000
 10000 1702.8000
 10000 1705.9000
 10000 1709.0000
 10000 1712.1000
 10000 1715.2000
 10000 1718.3000
 10000 1721.4000
 10000 1724.5000
 10000 1727.6000
 10000 1730.7000
 10000 1733.8000
 10000 1736.9000
 10000 1740.0000
 10000 1743.1000
 10000 1746.2000
 10000 1749.3000
 10000 1752.4000
 10000 1755.5000
 10000 1758.6000
 10000 1761.7000
 10000 1764.8000
 10000 1767.9000
 10000 1771.0000
 10000 1774.1000
 10000 1777.2000
 10000 1780.3000
 10000 1783.4000
 10000 1786.5000
 10000 1789.6000
 10000 1792.7000
 10000 1795.8000
 10000 1798.9000
 10000 1802.0000
 10000 1805.1000
 10000 1808.2000
 10000 1811.3000
 10000 1814.4000
 10000 1817.5000
 10000 1820.6000
 10000 1823.7000
 10000 1826.8000
 10000 1829.9000
 10000 1833.0000
 10000 1836.1000
 10000 1839.2000
 10000 1842.3000
 10000 1845.4000
 10000 1848.5000
 10000 1851.6000
 10000 1854.7000
 10000 1857.8000
 10000 1860.9000
 10000 1864.0000
 10000 1867.1000
 10000 1870.2000
 10000 1873.3000
 10000 1876.4000
 10000 1879.5000
 10000 1882.6000
 10000 1885.7000
 10000 1888.8000
 10000 1891.9000
 10000 1895.0000
 10000 1898.1000
 10000 1901.2000
 10000 1904.3000
 10000 1907.4000
 10000 1910.5000
 10000 1913.6000
 10000 1916.7000
 10000 1919.8000
 10000 1922.9000
 10000 1926.0000
 10000 1929.1000
 10000 1932.2000
 10000 1935.3000
 10000 1938.4000
 10000 1941.5000
 10000 1944.6000
 10000 1947.7000
 10000 1950.8000
 10000 1953.9000
 10000 1957.0000
 10000 1960.1000
 10000 1963.2000
 10000 1966.3000
 10000 1969.4000
 10000 197

D3/150

CEL MEMO: DECEMBER 29, 1986

FMC Central Engineering Laboratories
Santa Clara

Interoffice

To Larry Libhardt Date Dec. 29, 1986

From C. R. Ortloff cc E. Thuse
A. Amberg
R. Kazares
J. Ries
R. Rathe
E. Alexander
B. Zierwick

Subject STRESS RESULTS FOR THE 0° ROTATION,
72° ELEVATION LWHD CONFIGURATION (GIMBAL,
PLATFORM SPADE, TRAILS) UNDER PROOF LOADS.
(114 FIGURES ATTACHED)

Attached are figures 270-384 showing dynamic deflection histories at MDOF nodes on the LWHD structure. Locations of many of these MDOF points have been previously given (Memo: CRO to L. Libhardt, 17 Dec 86). Boundary conditions for these runs are those of a fixed lower spade edge and UY=0 on the horizontal plate resting on the ground (hard ground emplacement assumption). The cradle is free to rotate about its gimbal mount point in the (vector) x-direction with only the cable providing a restraint against rotation. The model has been described in detail in a prior memo (Memo: CRO to L. Libhardt, 22 Dec 86).

Scales of figures 271-273, 275-277 and 281-288 should be normalized to zero deflection at zero time. The deflection scale normalization is necessary due to the fact that separate files (and coordinate systems) were appended to the cradle/gimbal file to form the total system model.

Figures 271-273 show a deflection-time history for a node (N 2915) on the cable (figure 270). The cable has a small EI value to insure its flexibility; this will produce a conservative deflection effect as the cable is not allowed to contribute any resistance to compressive bending effects along its length. The modulus is correctly chosen, however, to account for stretching effects under tension loads. Results indicate about a maximum of 0.5 inch UZ deflection (global coordinates), a maximum of 0.65 inch UY deflection and a maximum 0.07 inch UX deflection under load indicating that the cable/cradle system is stable for times between 0 and 1 second (the calculation time range). Since the masses of the cradle and cables are duplicated as well as the rotary moment of inertia of the cradle, the dynamic motion of the cradle/cable system can (at least) be estimated. Since the stiffness matrix of the cradle has not been exactly duplicated in the current FE model, the bending, twisting and compression effects of the cradle on the cable motion are not exact. Use of beam elements (figure 270) with high rigidity comprise the cradle and allow for limited flexibility in all coordinate directions. In final analysis, the cable/cradle system appears stable during and after firing and torque loads have been applied with the current approximate representation of the cradle/cable.

Figure 274 represents the UY (vertical) deflection of a node on the trails (see figure 270). This part has been modeled after the 12

Larry Libhardt
Stress Results for the 0° Rotation,
72° Elevation LWHD Configuration (Gimbal,
Platform Spade, Trails) under Proof Loads.

Dec. 29, 1986
Page 2

Nov 86 drawing. As of 28 Dec 86 no drawings have been received of the trails to permit an upgrade in the FE model over the version described in the Memo: CRO to L. Libhardt, 22 Dec 86. Deflection in the UY direction indicates about a 0.25 inch "springback" liftoff of the trail and subsequent relaxation to a rest position, i.e., trail motion is stable under 0°-72° firing loads. Note that "rest" deflection asymptotes in all figures reflect the 1g gravity load static deflection.

gun w → Figures 275-277 show the motion of N2976 on the cable (figure 270). In general, the same conclusions regarding the cable motion and its stability can be drawn from these figures as for those discussed earlier. Figure 278 and 279 represent further trail MDOF nodes. The deflection stability at these nodes can be seen from the figures. Figures 287-288 represent the motion of the gun barrel tip. Again, the stiffness matrix of the cradle represented by near rigid beam elements only estimates cradle bending and deflection effects approximately but does allow for its "rigid body" motion due to the correct representation of mass and rotary inertia effects. The gun barrel tip motion is therefore only approximate. Also, the barrel moves in the Z direction with time, further rendering the estimates for barrel tip motion less valid with increasing time. Nevertheless, the estimates provided give an indication of stability of the system under dynamic firing loads. As can be seen from these figures, maximum vertical deflection of the barrel tip appears to be about 2 inches while maximum X deflection is about 0.5 inches. While most oscillations are sufficiently damped after one second using DAMP=0.2%, an upgrade on the Kevlar cable damping values will provide further detailed information on the effect of the cable on system stability. Better representation of the dynamics of the cradle/cable system await final design decisions on the redesign of the original cradle configuration in order to represent its stiffness matrix more correctly. Estimates of the motion of the barrel tip, with approximate representations of the dynamic properties of the cradle/cable system, nevertheless reveal a stable system with acceptable barrel travel dynamics. Presumably, the redesign of the cradle will be slanted toward a stiffer system than presently exists rendering the current approximate FE model of the cradle closer to the next design stage.

The remaining figures detail dynamic deflection histories for MDOFs on the platform/gimbal system. Locations of many of these nodes are detailed in the Memo: CRO to L. Libhardt, 22 Dec 86. The dynamic deflections are generally less than 1.0 inches in all (global) coordinate directions. From these figures, times at which maximum

dynamic deflection amplifications exist (here chosen as 0.046, 0.031 and 0.258 sec.) correspond to maximum stress states in the gimbal and platform.

For the 0.046 second case, figures 307-331 give Von Mises equivalent stress results on the outside Ti surfaces of the gimbal and platform. Results are summarized below.

- o Zones around the shaft connection openings in the gimbal fail locally as stresses exceed 80 ksi. This holds true for the two openings on the top box beam as well as the two bottom box beam elements. This type of local failure was also observed for the 0°-0° case (Memo CRO to L. Libhardt, 17 Dec 86) under proof loads. These zones can be easily reinforced with weld-on or bolt-on plates around the gimbal shaft openings.
- o The lower gimbal-cradle attachment arms have local stresses exceeding yield stress (figure 310 for example). The reinforcement weld-ons appear to fail as stresses exceed yield stress by 40 ksi. These reinforcements need to be modified significantly to sustain the 0°-72° firing loads without failure.
- o The upper gimbal-cable arms appear to be adequate to sustain firing loads (together with the gravity load).
- o Triangular reinforcing plates (figures 316-318) appear overstressed especially in the central portion of the platform. Stresses are about 80 ksi maximum (figure 316) and indicate local yielding is probable.
- o Stresses in both top and bottom platform shaft tabs (figures 319, 320) appear to be sufficiently low to not fail under load.
- o Stresses in the upper box beam of the platform are very close to yield stress for Ti (figure 324). The upper box beam needs to be reinforced (additional thickness is sufficient) to lower these values. The presence of a welded box beam structure introduces the need for a reasonable safety factor to account for weld defects and the concomitant local stress concentration factors.
- o Maximum bottom shaft stress is 29800 psi at Node 3388 from figures 329-330.
- o Top shaft stress is about 40 ksi.

Results at 0.258 second are as follows:

- o Stresses in the top gimbal to cradle arms again exceed yield

Larry Libhardt
Stress Results for the 0° Rotation,
72° Elevation LWHD Configuration (Gimbal,
Platform Spade, Trails) under Proof Loads.

Dec. 29, 1986
Page 4

stress (similar to results from the 0.046 sec case). (See figure 342, 348 for example.) These upper arms need to be reinforced as well as the local connecting structure (figure 349, 350 for example) on the gimbal.

- o Global vertical UY deflection of the gimbal appears large (figure 360) in the region of the lower arms corroborating the high stress values in these zones. Remaining UZ and UX deflections are small.
- o Bottom shaft stress is about 10 ksi, top shaft stress is about 40 ksi (figures 366-377).

Results from the 0.031 second run are as follows:

- o Stresses for both upper and lower gimbal arms exceed yield stress under proof loads (figure 376 for example). These arms need reinforcement as indicated by this and the prior two time cases.
- o The gimbal upper and lower box beam shaft openings similarly exceed yield stresses and need reinforcement (see figure 376 for example). Without reinforcement in these zones, gimbal failure is imminent as yield stresses are exceeded by as much as 20-40 ksi (see figure 378 for example).
- o Bottom shaft stress is about 21 ksi; top shaft stress is about 40 ksi (see figures 381-382).

General conclusions for the 0°-72° load case:

- o The upper and lower gimbal arms appear to fail under dynamic load as stresses can exceed yield stress by 20-40 ksi.
- o The gimbal shaft openings for both upper and lower box beams fail locally around the opening zone. Local reinforcement in the form of weld-on or bolt-on box beams is required to prevent part failure.
- o In general, both platform and gimbal in regions away from local failure zones exhibit stresses that can be as high as half of the yield stress. In that a welded box beam Ti structure is used for both platform and gimbal, a reasonable safety factor must be used to allow for weld defects causing local stress concentrations.

Larry Libhardt
Stress Results for the 0° Rotation,
72° Elevation LWHD Configuration (Gimbal,
Platform Spade, Trails) under Proof Loads.

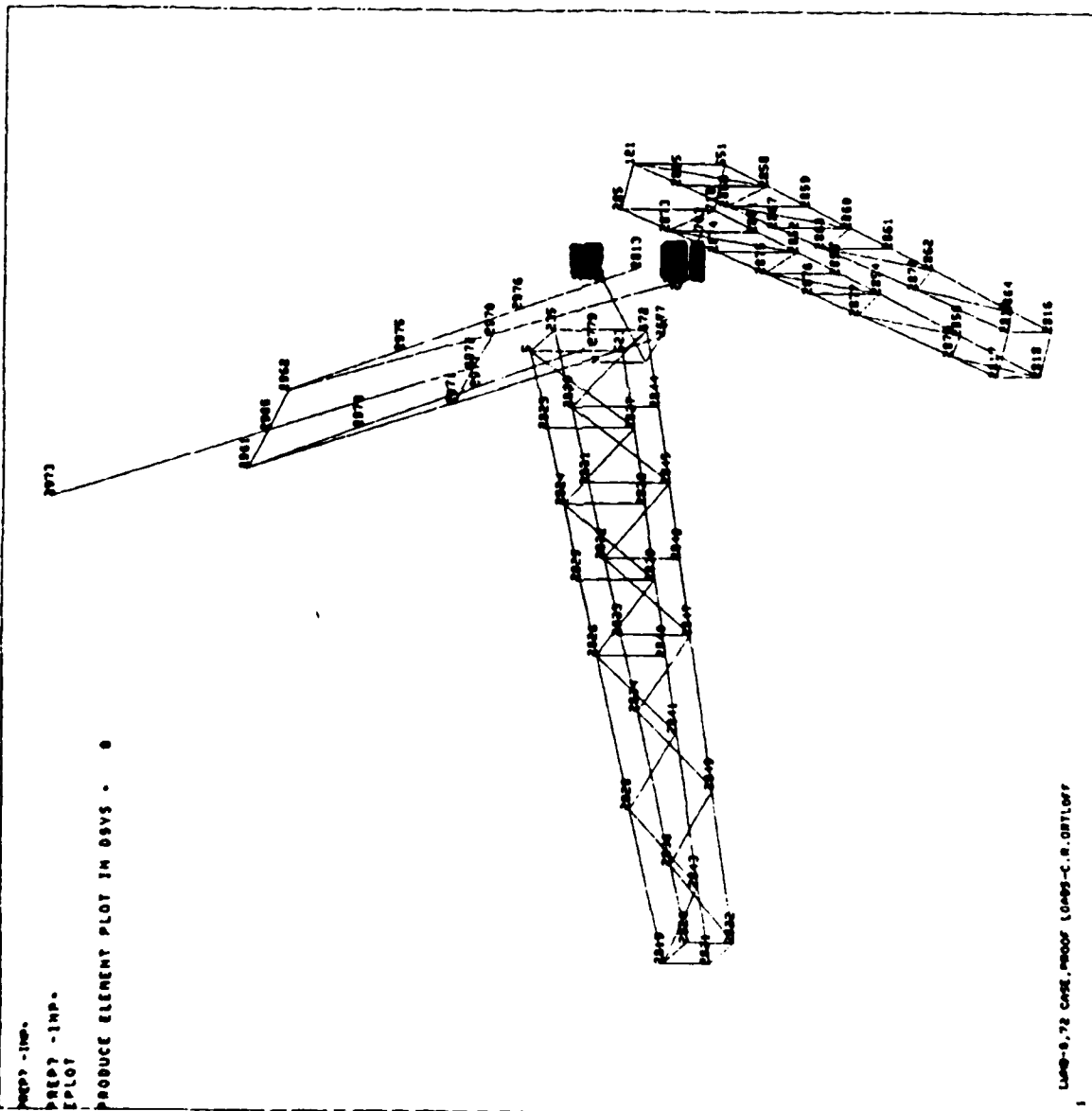
Dec. 29, 1986
Page 5

- o The total system appears stable under firing loads and no overturning or "gun whip" excursions appear to exist. The cable seems to induce vibrational (rigid body) oscillations into the cradle (figures 271-273 for example) which may be very damaging to gun pointing accuracy if the oscillations are not sufficiently damped before the next firing.
- o Shaft stress for all times indicated are less than 40 ksi.

Results of the 0°-72° case confirm some prior findings of the 0°-0° case (Memo: CRO to L. Libhardt, 22 Dec 86) in that reinforcement of the gimbal upper and lower shaft attachment zones is called for to reduce local stresses. The additional result for the 0°-72° case shown in the present memo is that the gimbal upper and lower arms need also to be reinforced to prevent failure. Since these changes require additional thickening and/or bolt-on plates, the current design can be modified to achieve the necessary strength margins. Since the 22.5°-72° case has also been completed, it is suggested that results from this case be examined before new structural revisions are made in order to judge the sum total of all failure zones.


C. R. Ortloff

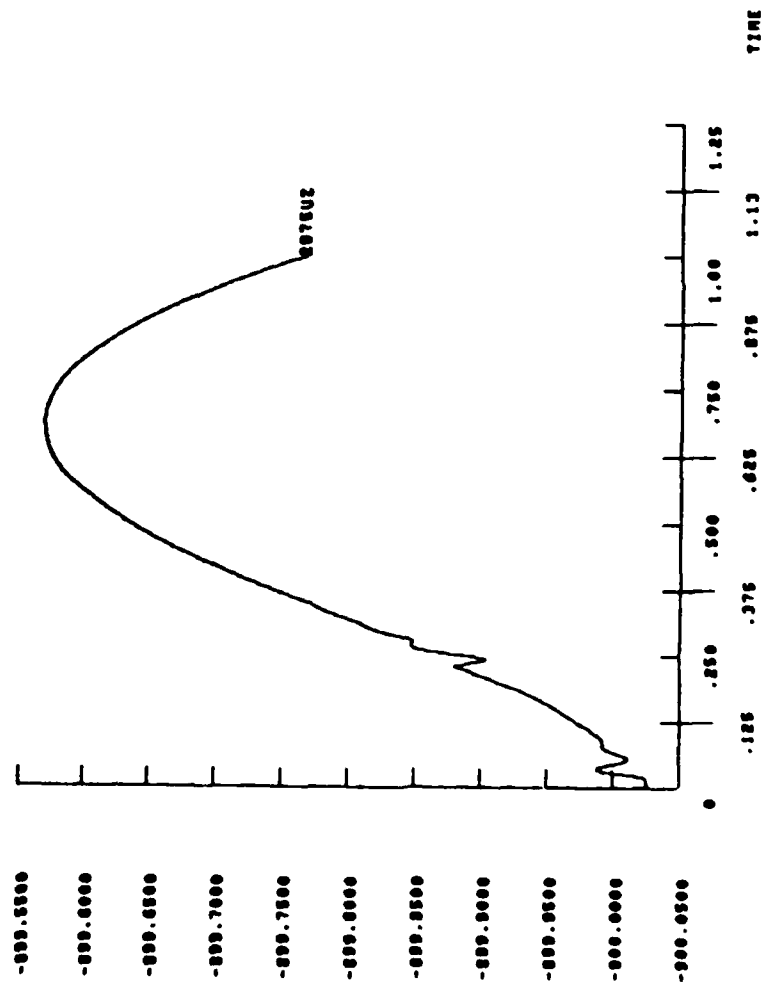
00000 0.00
 SEC 10 1000
 10102101
 PREP7 ELEMENTS
 MODUL-1
 MU-1
 VU-1
 20-1
 210T-061
 10-06.1
 V7-132
 27-130
 1070-0.03
 1070-1.00



*****COMPLETE FOR 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES
 VARIABLE IDENTIFIERS NAME MINIMUM AT TIME MAXIMUM AT TIME
 2 212P 2075 U2 2075U2 -999.0 0.3000E-02 -999.0 0.0030

PLOT DEFINITION
 CURVE VARIABLE NAME
 1 2075U2



1 LUMB-0.72 CASE, PROOF LOADS-C.B. ONTLOFF

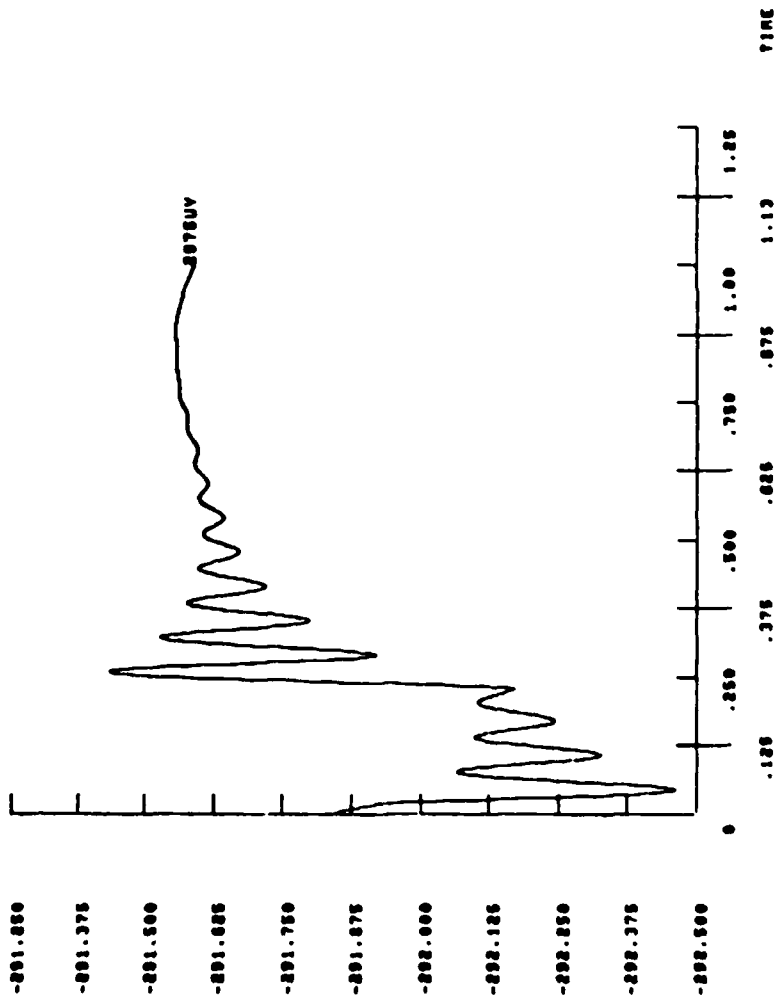
INCOMPLETE FOR 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES

JOB1 TYPE IDENTIFIERS NAME MINIMUM AT TIME MAXIMUM AT TIME

2 518P 2075 UV 2075UV -202.5 0.4400E-01 -201.4 0.2500

PLOT DEFINITIONALLY
CURVE VARIABLE NAME
1 2075UV
2 2075UV



1 LUND-0.72 CASE, PROOF LOADS-C.R.-007L077

*****COMPLETE FOR 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES

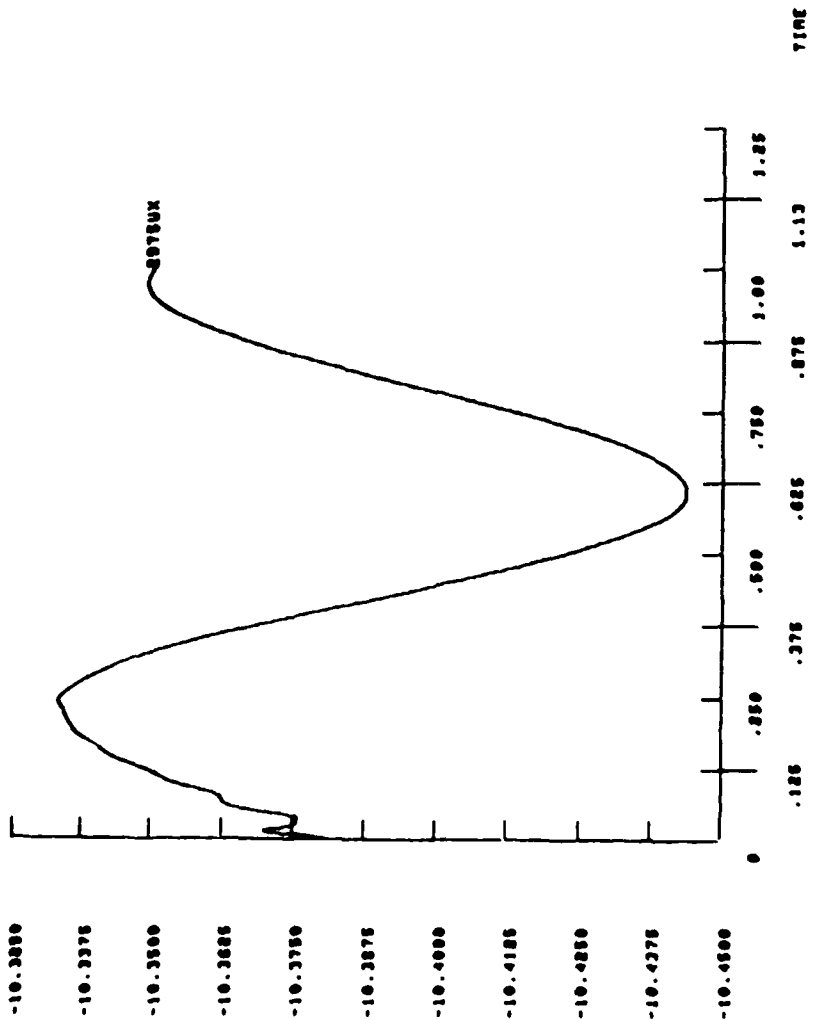
NAME TYPE IDENTIFIERS NAME MINIMUM AT TIME MAXIMUM AT TIME

8 010P 0076 UN 0076UN -10.44 0.0070 -10.23 0.2410

PL0Y DEFINITIVE

CURVE VARIABLE NAME

1 0076UN



1 LUMB-0.72 CASE, PROOF LOADS-C.B.ORTLOFF

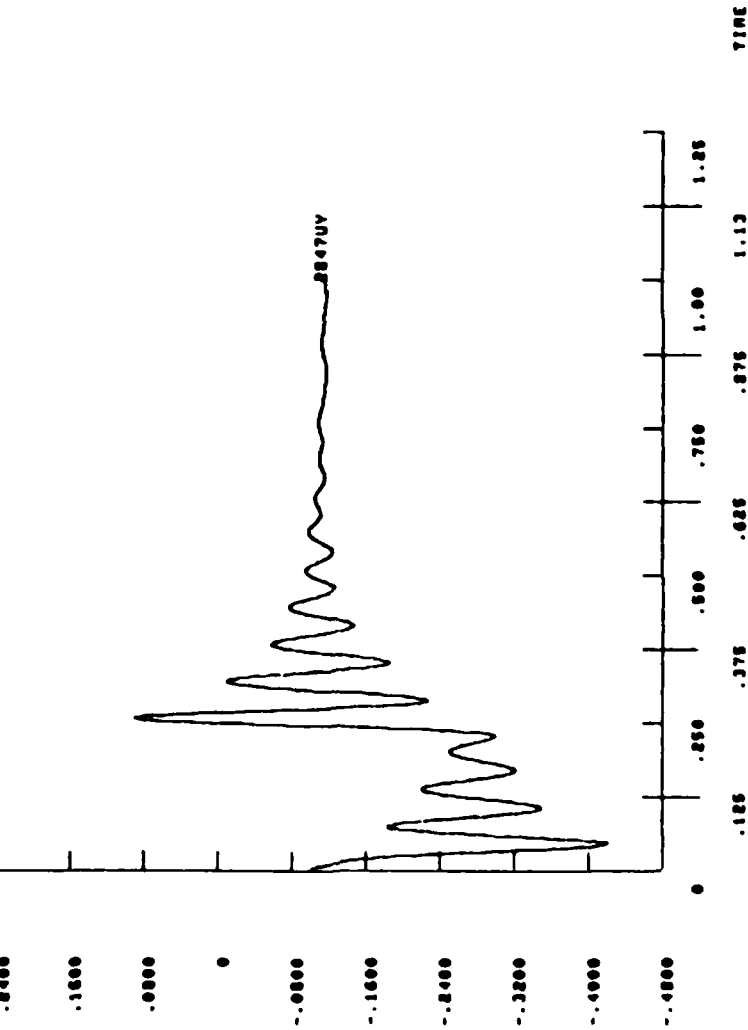
POSTED-IMP.
 VARIABLE 2 IS 2847 UV PHASE REV. 0
 POSTED-IMP.
 PLUG.0

STORAGE COMPLETE FOR 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES
 LAST TYPE IDENTIFIERS NAME MINIMUM AT TIME MAXIMUM AT TIME

2 0102 2847 UV 2847UV -0.4818 0.4700E-01 0.8977E-01 0.8880

PLOT DEFINITION
 CURVE VARIABLE NAME
 1 2847UV



1 LUND-0.72 CASE, PROOF LOADS-C.R. ONTLOFF

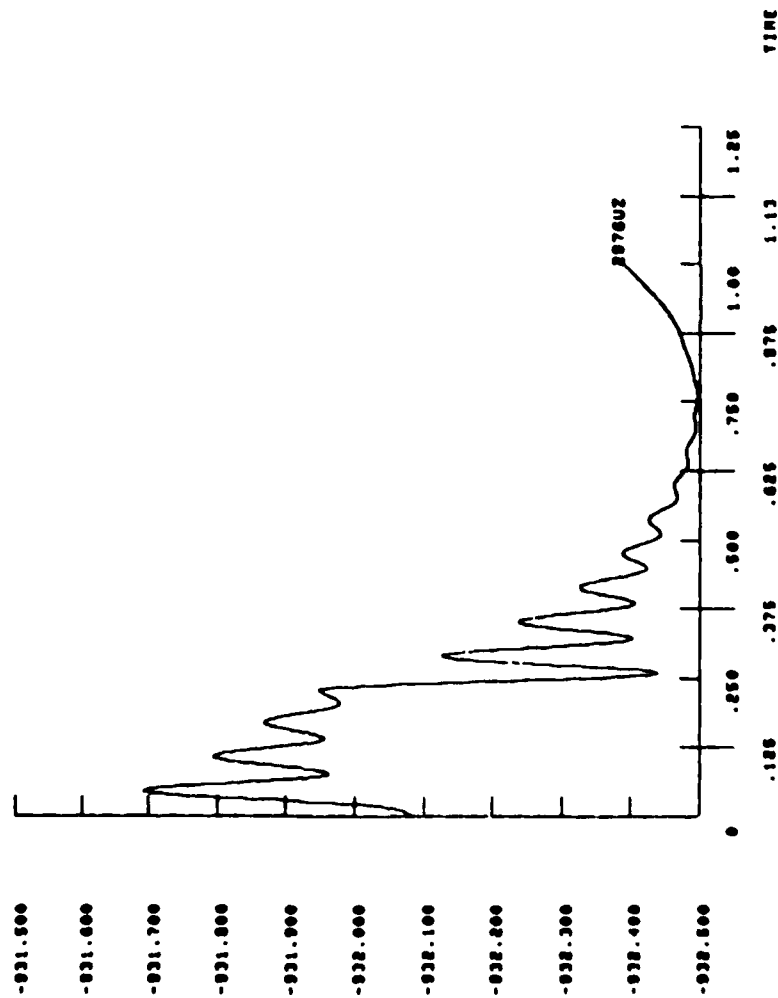
*****COMPLETE FOR 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES

1001 TYPE IDENTIFIERS NAME MINIMUM AT TIME MAXIMUM AT TIME

8 DISP 2076 U2 2076U2 -032.8 0.7500 -031.7 0.4500E-01

PLOT DEFINITION
CURVE VARIABLE NAME
1 2076U2

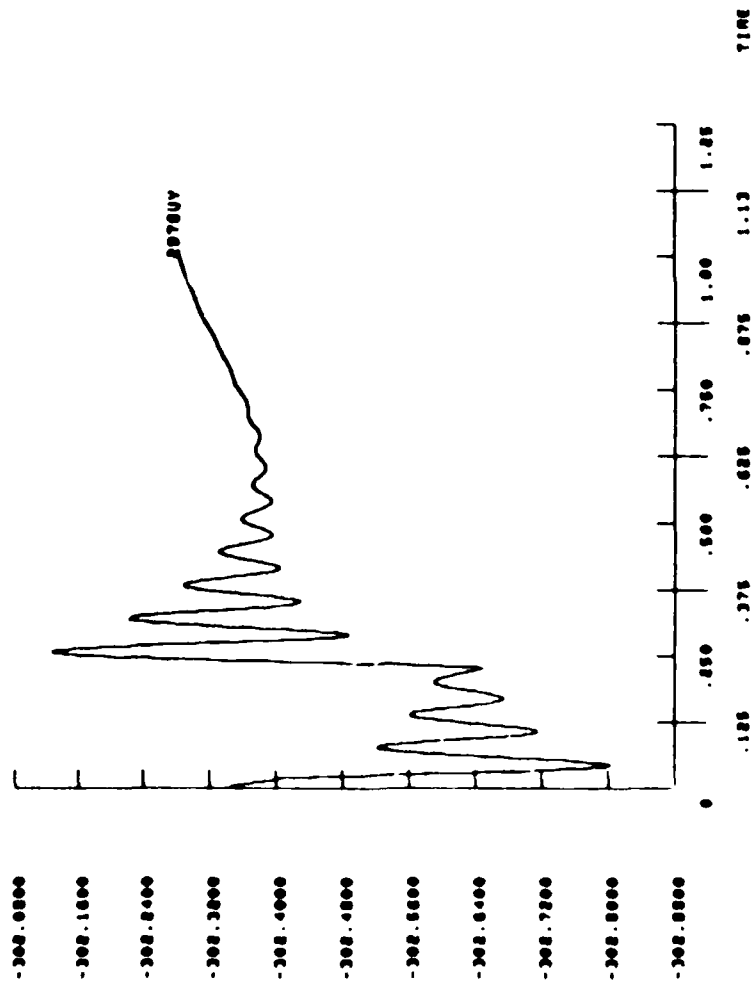


1 LUMB-0.72 CASE, PROOF LOADS-C.D. 087L077

*****INCOMPLETE FOR 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES
 NAME TYPE IDENTIFIERS NAME MINIMUM AT TIME MAXIMUM AT TIME
 Q 0130 0076 UV 0076UV -302.0 0.4300E-01 -302.1 0.8570

PLOT DEFINITION
 X=Q 0130 0076 UV
 Y=Q 0130 0076 UV



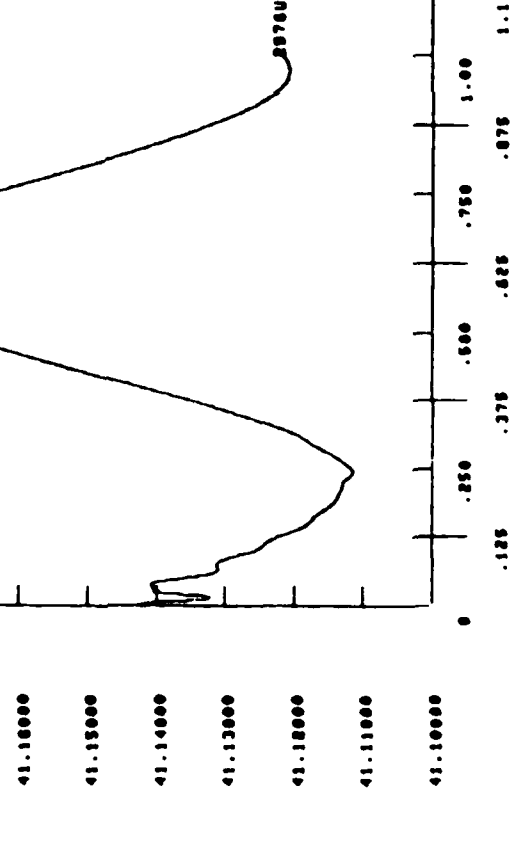
1 LUND-0.72 CASE, PROOF LOADS-C.B. OUTLOFF

POSTPROCESSING- MODE 2005 DIR- UX IS NOT A MASTER D.O.F.
 BEGINNING 200
 NO DATA POINTS SAVED THIS STORAGE STEP
 CP- 307.0400 TIME- 18.94103
 POST700-IMP.
 PLOT 0.2070,UX

POSTS WARNING- 0005 DIR- UX IS NOT A MASTER D.O.F.
 BEGINNING 200
 NO DATA POINTS SAVED THIS STORAGE STEP
 CP- 308.8700 TIME- 18.94700
 VARIABLE 2005 2070 PZ PHASE REV- 0
 POST700-IMP.
 PLOT 0

STORAGE COMPLETE FOR 7001 DATA POINTS
 SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES
 NAME TYPE IDENTIFIER NAME MINIMUM AT TIME MAXIMUM AT TIME
 0 010P 2070 UX 2070UX 41.11 0.430 41.18 0.0000

PLOT OF 100000
 CURVE CONTINUED NAME
 1 2070UX

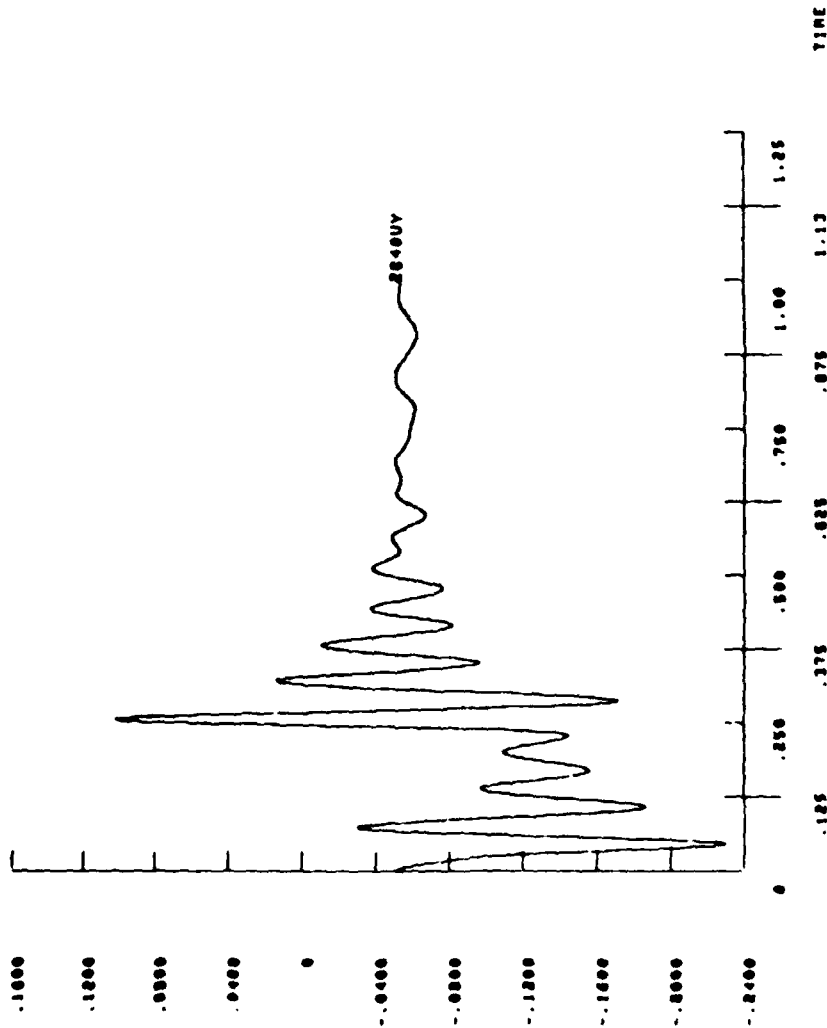


1 LUND-0.72 CASE,PROOF LOADS-C.R.ORTLOFF

*****COMPLETE FOR 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES
 NAME TYPE IDENTIFIERS NAME MINIMUM AT TIME MAXIMUM AT TIME
 2 B10P 2040UV 2040UV -0.8300 0.4600E-01 0.1017 0.8550

PLOT DEFINITION
 CURVE VARIABLE NAME
 1 2040UV



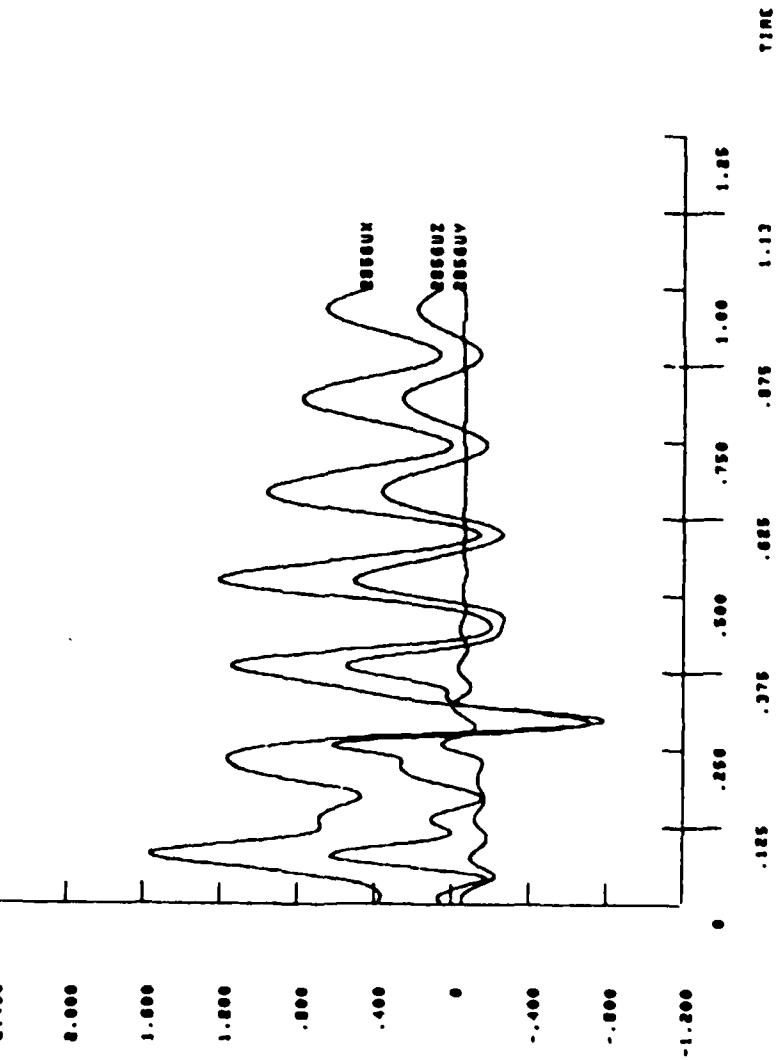
1 LUMB-0.72 CASE, PROOF LOADS-C.B. ONTLOFF

INCOMPLETE FOR 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES

| TIME | MINIMUM | AT TIME | MAXIMUM | AT TIME |
|--------|---------|---------|---------|---------|
| 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |

NAME
 1. 0.0000
 2. 0.0000
 3. 0.0000
 4. 0.0000



1. LUND-9.72 CASE, PROOF LOADS-C.R. ONTLOFF

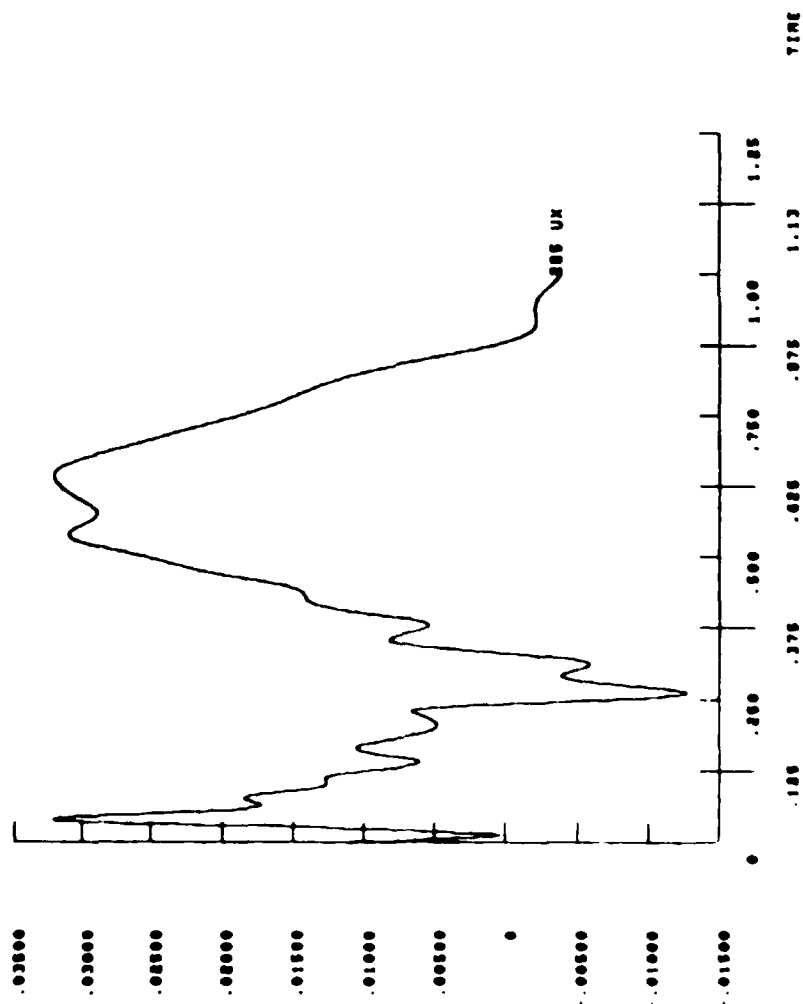
*****COMPLETE FOR 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES
 LAST TYPE IDENTIFIERS NAME MINIMUM AT TIME MAXIMUM AT TIME

2 DISP 205 UX 205 UX -0.1272E-01 0.2620 0.3217E-01 0.6430

PLOT DEFINITION

CURVE VARIABLE NAME
 2 205 UX

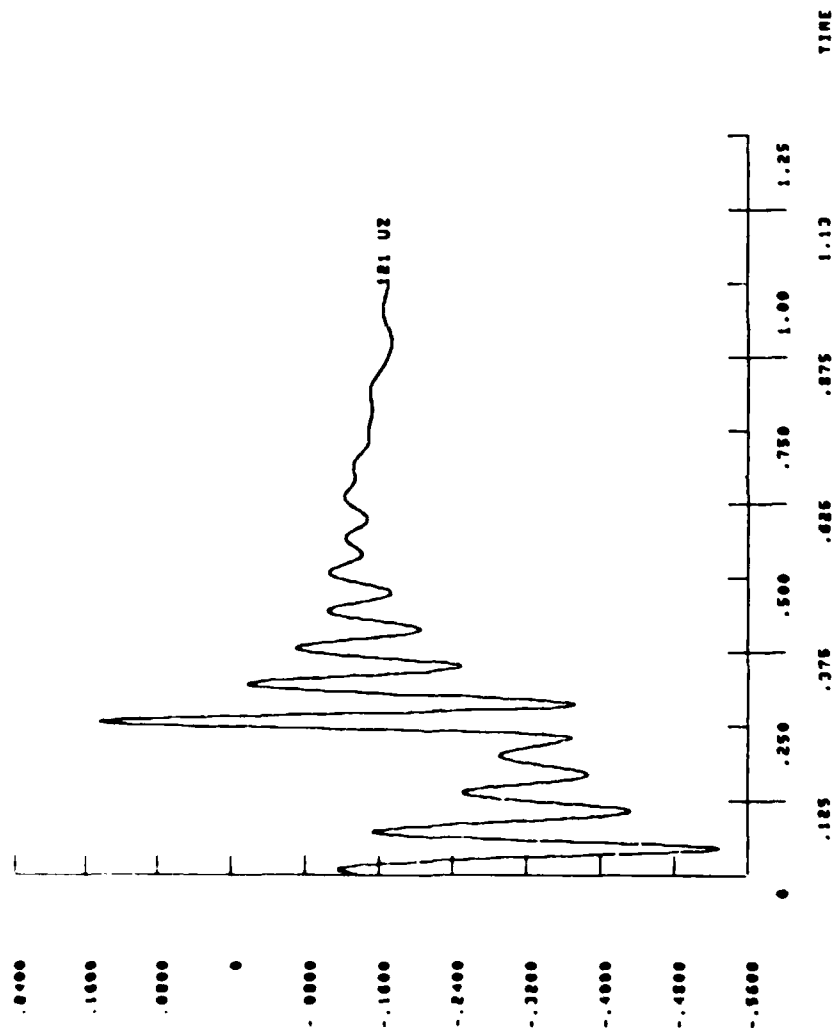


1 1000-0.72 CASE, PROOF LOADS-C.B. ONLY 077

*****COMPLETE FOR 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES
 POST TYPE IDENTIFIERS NAME MINIMUM AT TIME MAXIMUM AT TIME
 0 STOP VALU UZ 101 UZ -0.0000 0.00000E-01 0.1000 0.0000

PLOT DEFINITION
 CURVE VARIABLE NAME
 1 101 UZ



1 LUND-0.72 CASE, PROOF LOADS-C.R.ORTLOFF

INCOMPLETE FOR 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES

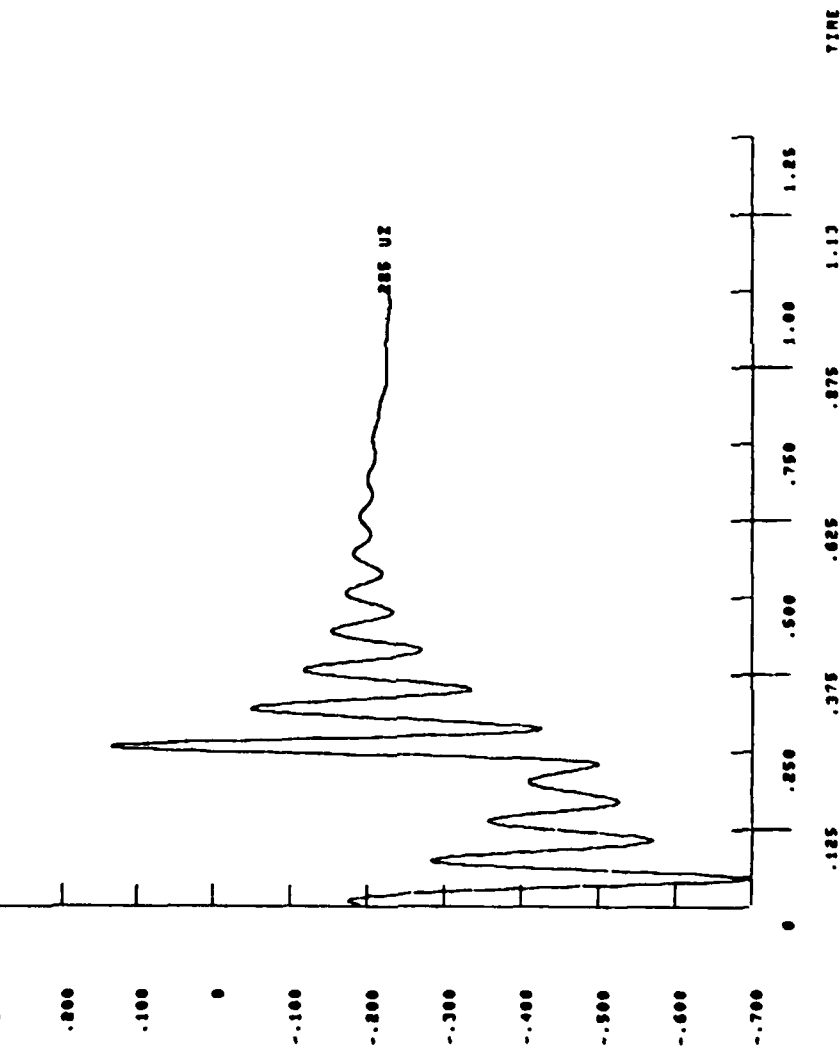
CASE TYPE IDENTIFIERS NAME MINIMUM AT TIME MAXIMUM AT TIME

0 STEP 1000 UZ 205 UZ -0.0000 0.4000E-01 0.1343 0.0000

PLOT DEFINITION

CURVE VARIABLE

1 205 UZ

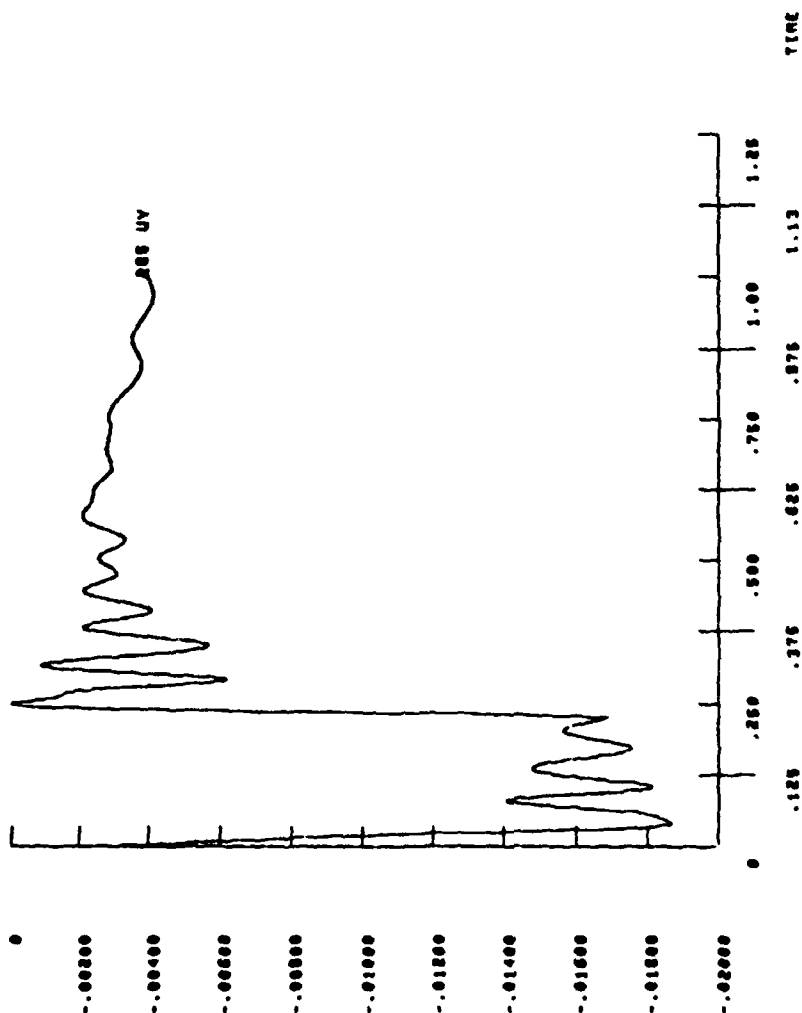


1 LUND-0.72 CASE, PROOF LOADS-C.R.ORTLOFF

INCOMPLETE FOR 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES
 NAME TYPE IDENTIFIED NAME MINIMUM AT TIME MAXIMUM AT TIME
 2 BISP 285 UV 285 UV -0.1007E-01 0.0000E-01-0.0223E-04 0.0000

PLOT DEFINITION
 CURVE VARIABLE NAME
 1 285 UV



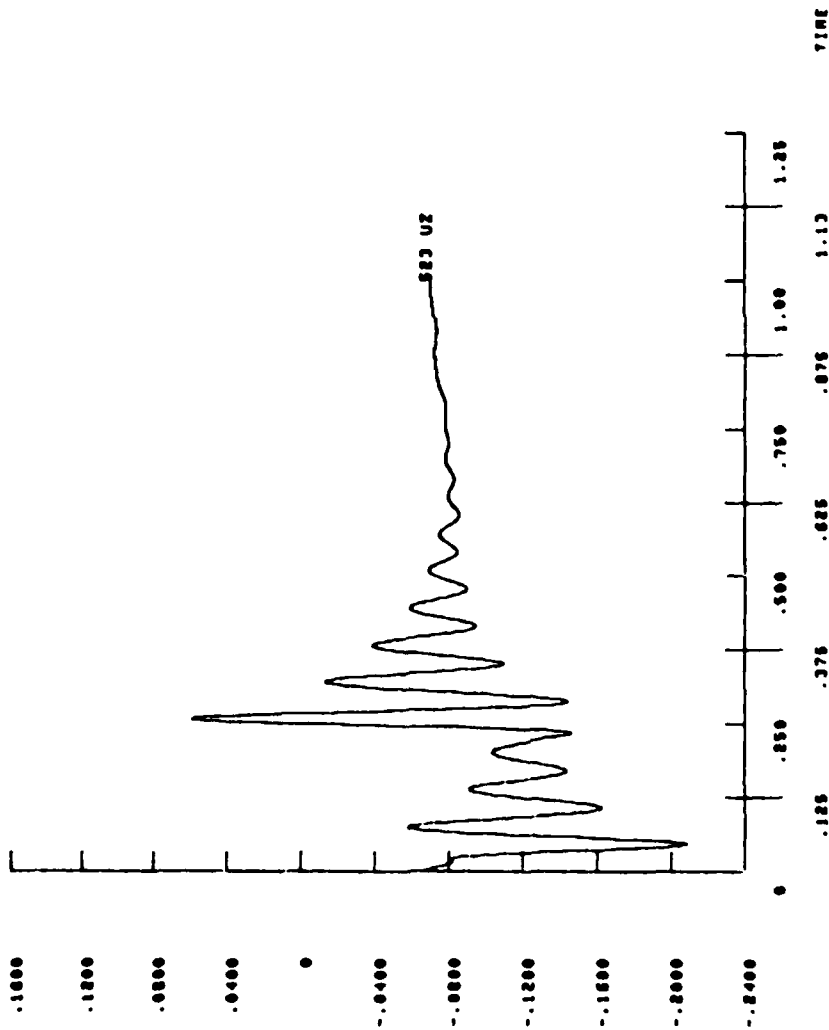
1 LUMB-0.72 CASE, PROOF LOADS-C.C. ORTLOFF

*****COMPLETE FOR 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES
 VARIABLE IDENTIFIERS HAVE MINIMUM AT TIME MAXIMUM AT TIME

2 B10P VALU UZ 823 UZ -0.0000 0.4700E-01 0.0000E-01 0.0000

PLOT DEFINITION
 CURVE VARIABLE NAME
 1 823 UZ



1 LUMD-0.72 CASE, PROOF LOADS-C.R.ORTLOFF

*****COMPLETE FOR 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES

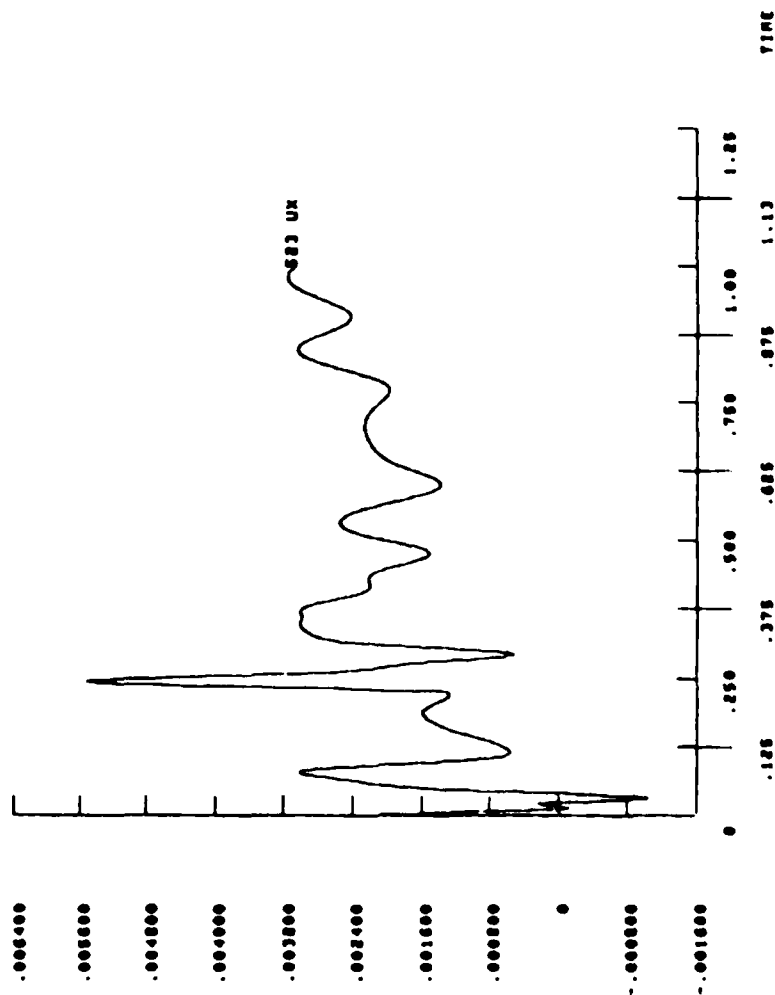
JOB1 TYPE IDENTIFIERS NAME MINIMUM AT TIME MAXIMUM AT TIME

2 DISP 823 UX 823 UX -0.1044E-02 0.3100E-01 0.0010E-02 0.0430

PLOT DEFINITION

CURVE VARIABLE NAME

1 823 UX

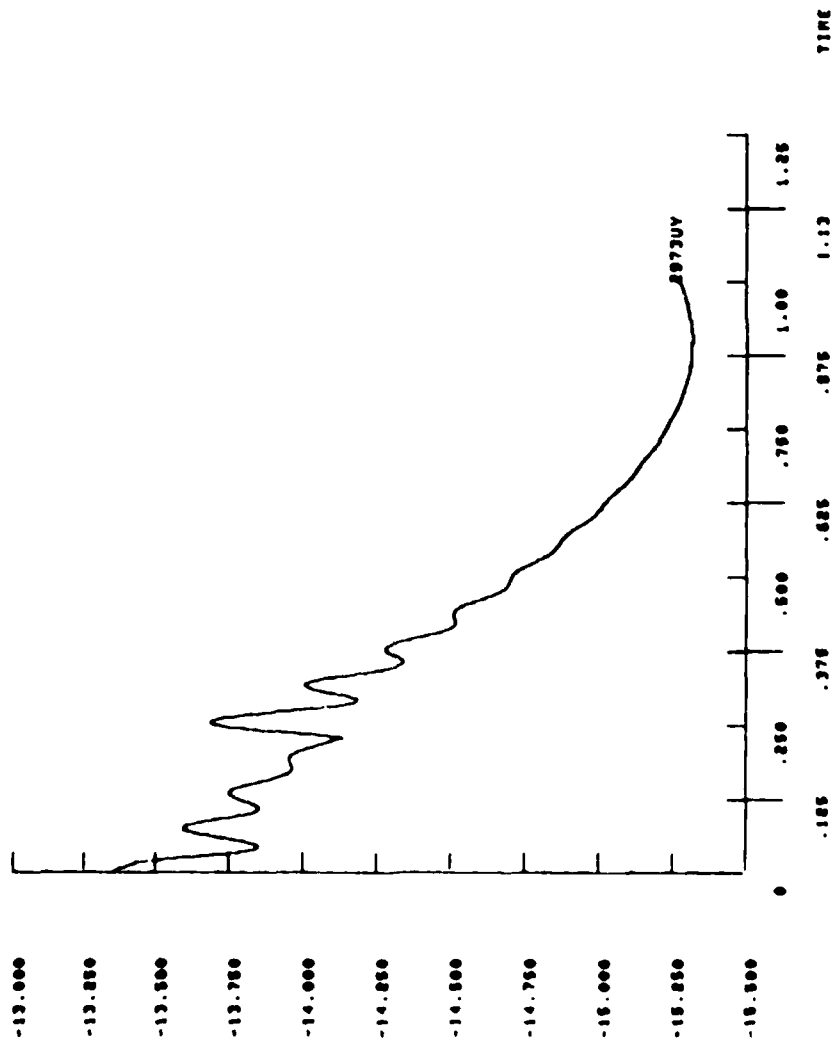


1 LUMP-0.72 CASE, PROOF LOADS-C.R. ONTLOFF

*****COMPLETE FOR 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES
 NAME TYPE IDENTIFIER NAME MINIMUM AT TIME MAXIMUM AT TIME
 0 STOP 0027UV 0073UV -15.31 0.0040 -13.36 0.8000E-08

PLOT DEFINITION
 1 VARIABLE NAME
 2 0073UV

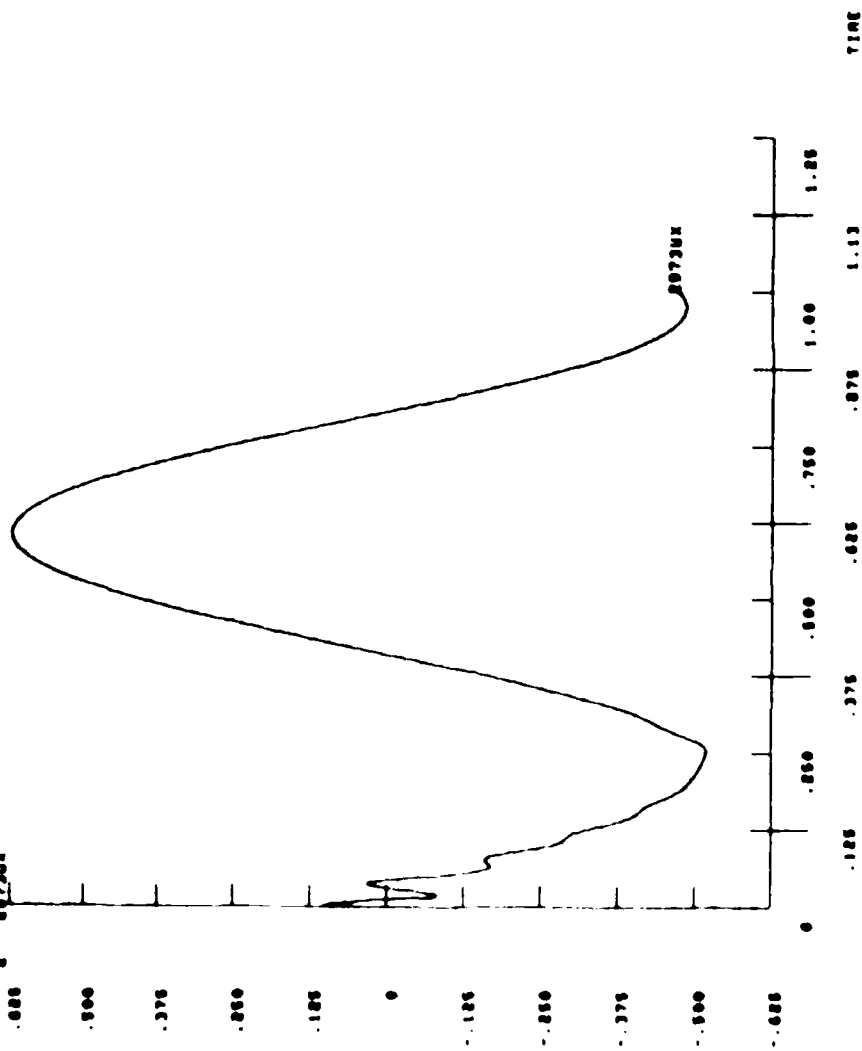


1.000E-072 CASE,0000F LOADS-C.R.0071OFF

*****COMPLETE FOR 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES
 NAME TYPE IDENTIFIERS NAME MINIMUM AT TIME MAXIMUM AT TIME
 1 DISP WVS IN 2073UX -0.0107 0.0010 0.0020 0.0040

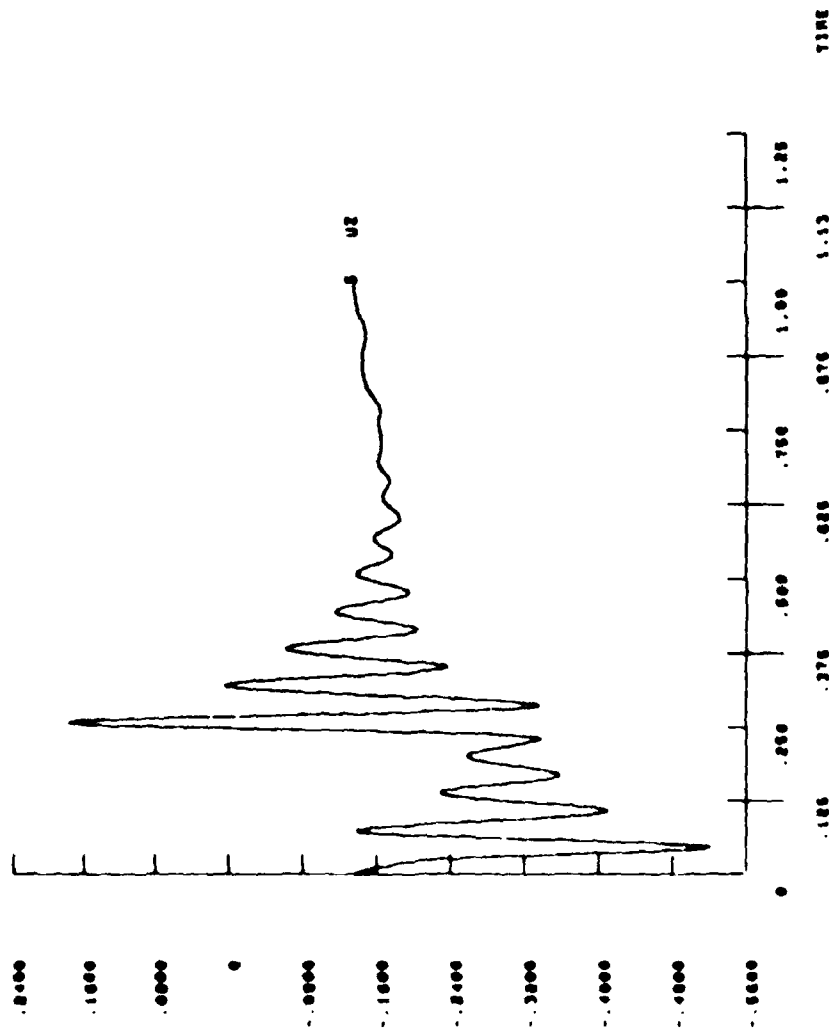
PLOT DERIVATION
 CURVE VARIABLE NAME
 1 2073UX



1 LUMB-0.72 CASE, PROOF LOADS-C.D. OUTLOFF

*****COMPLETE FOR 1001 DATA POINTS
 SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES
 NAME TYPE IDENTIFIER NAME MINIMUM AT TIME MAXIMUM AT TIME
 S STOP S UZ S UZ -0.5816 0.4000E-01 0.1771 0.0000

PLOT DEFINITION
 PLOT VARIABLE NAME
 1 S UZ

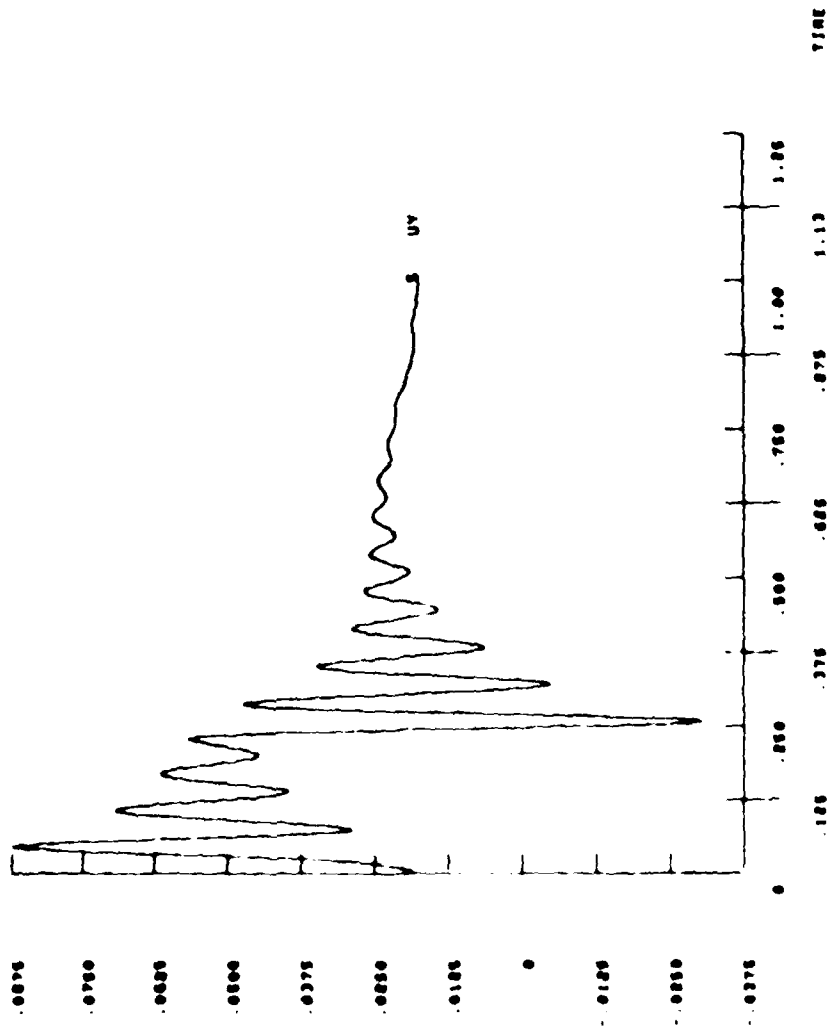


1 LUND-0.72 CASE, PROOF LOADS-C.6.00TLOFF

===== COMPLETE FOR 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES
 NAME TYPE IDENTIFIER NAME MINIMUM AT TIME MAXIMUM AT TIME
 A 0100 WAVELENGTH S UV -0.00000000 0.00000000 0.07400000 0.00000000

Plot description
 Name variable S UV

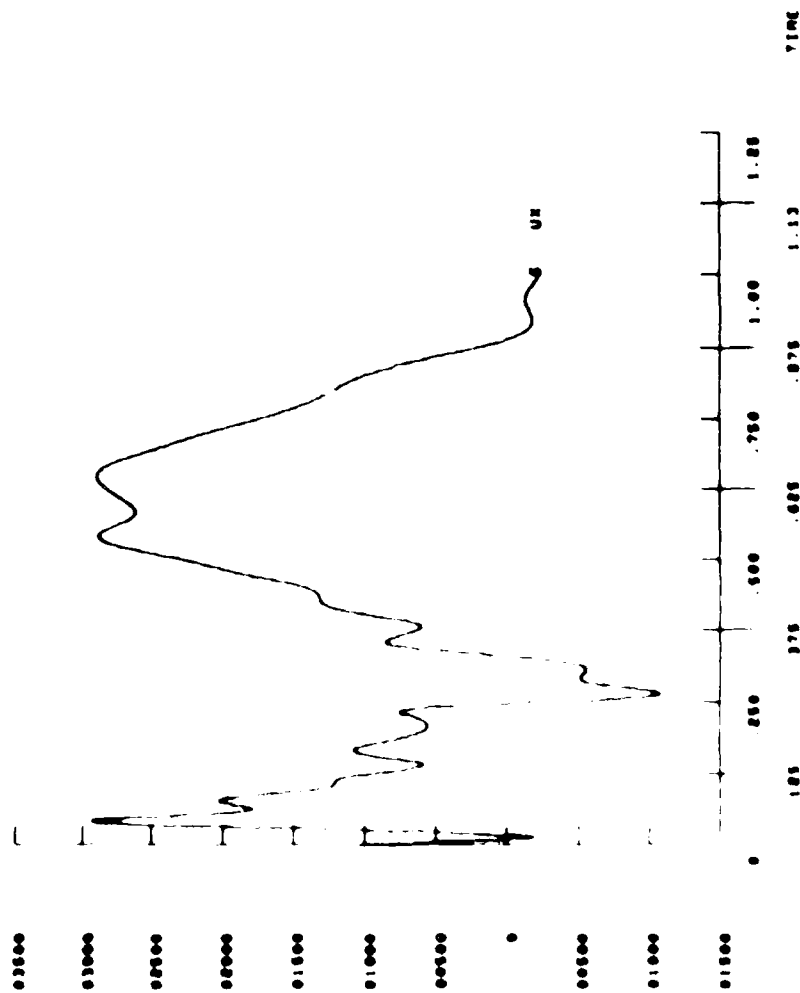


===== 1000-0.75 CASE 000000000000-0.00000000

*****COMPLETE FOR 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTENDED VALUES
 NAME TYPE INFORMATION NAME MINIMUM AT TIME MAXIMUM AT TIME
 0 0100 0 01 0 01 0.0000000 0.0000000 0.0000000 0.0000000

Plot derivative
 curve variable 0 01



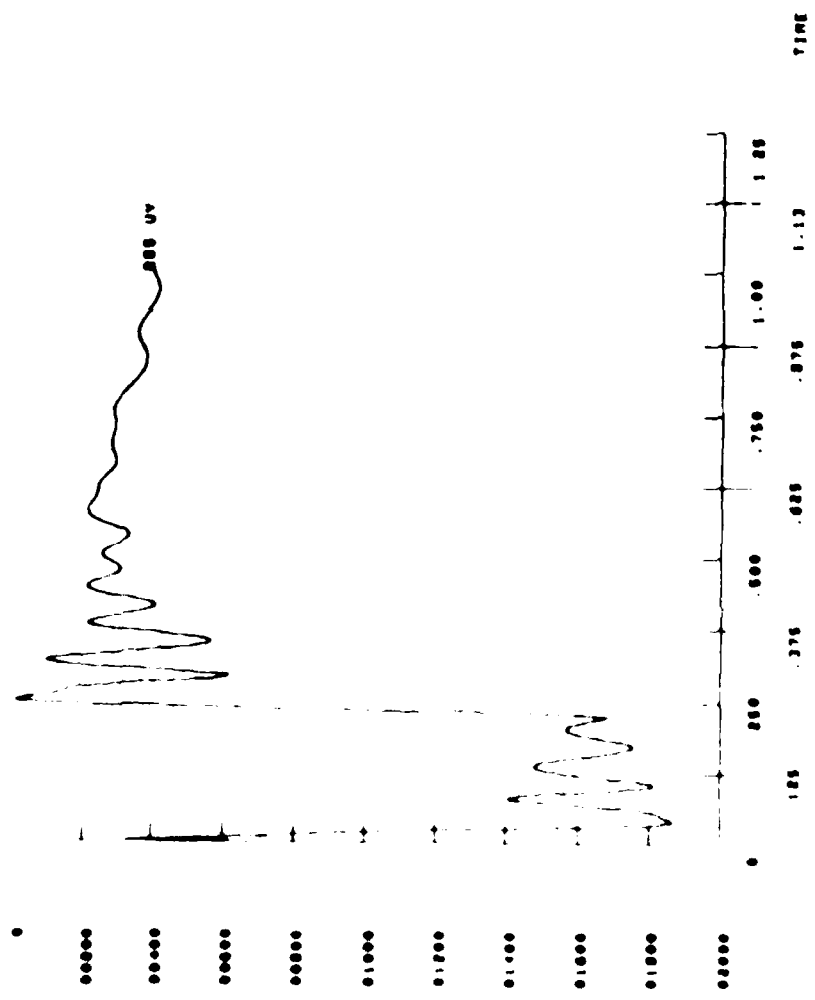
*****COMPLETE FOR 1001 DATA POINTS

*****COMPLETE FOR 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTREMUM VALUES
 NAME IDENTIFIED NAME MINIMUM AT TIME MAXIMUM AT TIME

0.0100 000 UV 000 UV -0.1007E-01 0.0000E-01 0.0000E-01 0.0000E-01 0.0000

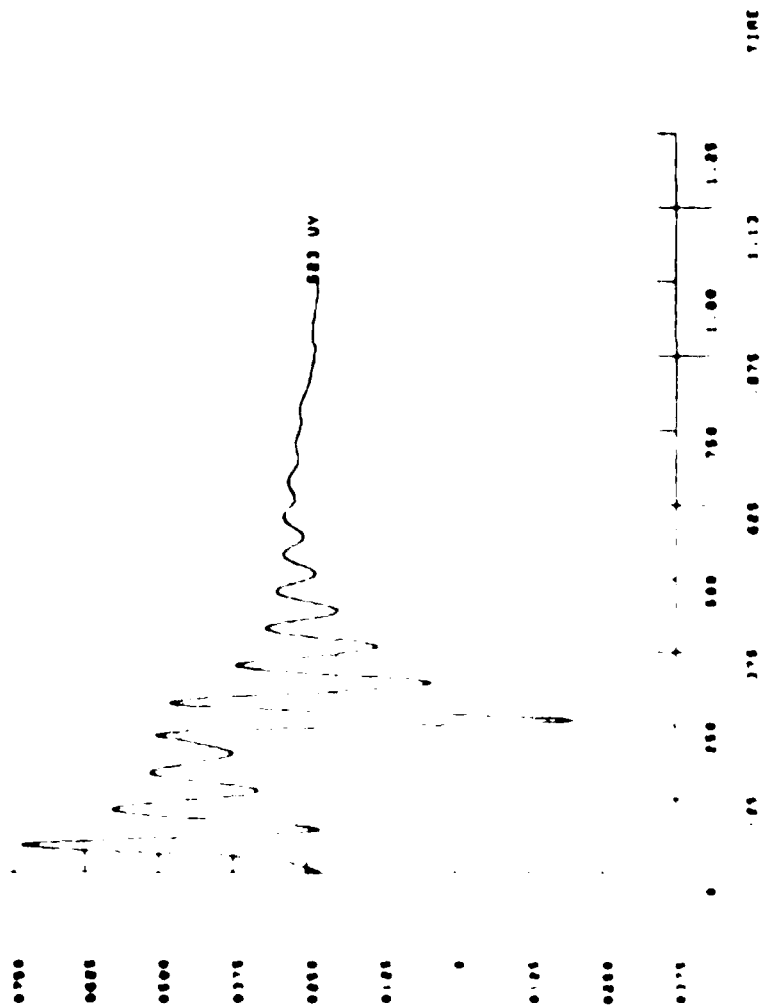
PLAY DEFINITION
 NAME VARIABLE NAME
 0 000 UV



*****END OF CASE *****

Summary of variables stored this step and saving values
 name value minimum at time maximum at time
 1 1000 1000 0 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000

Plot definition
 X-axis variable name
 Y-axis variable name
 1 1000 1000 0 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000

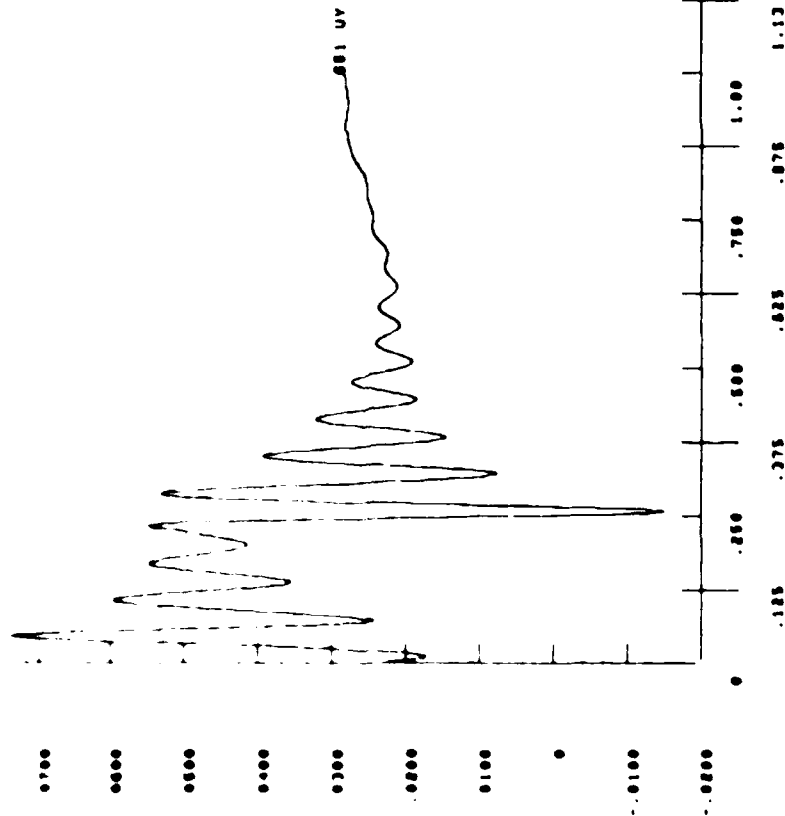


SUMMARY OF VARIABLES STORED INTO STEP AND AVERAGE VALUES

NAME OF VARIABLE STORED INTO STEP AND AVERAGE VALUES

NAME OF VARIABLE STORED INTO STEP AND AVERAGE VALUES

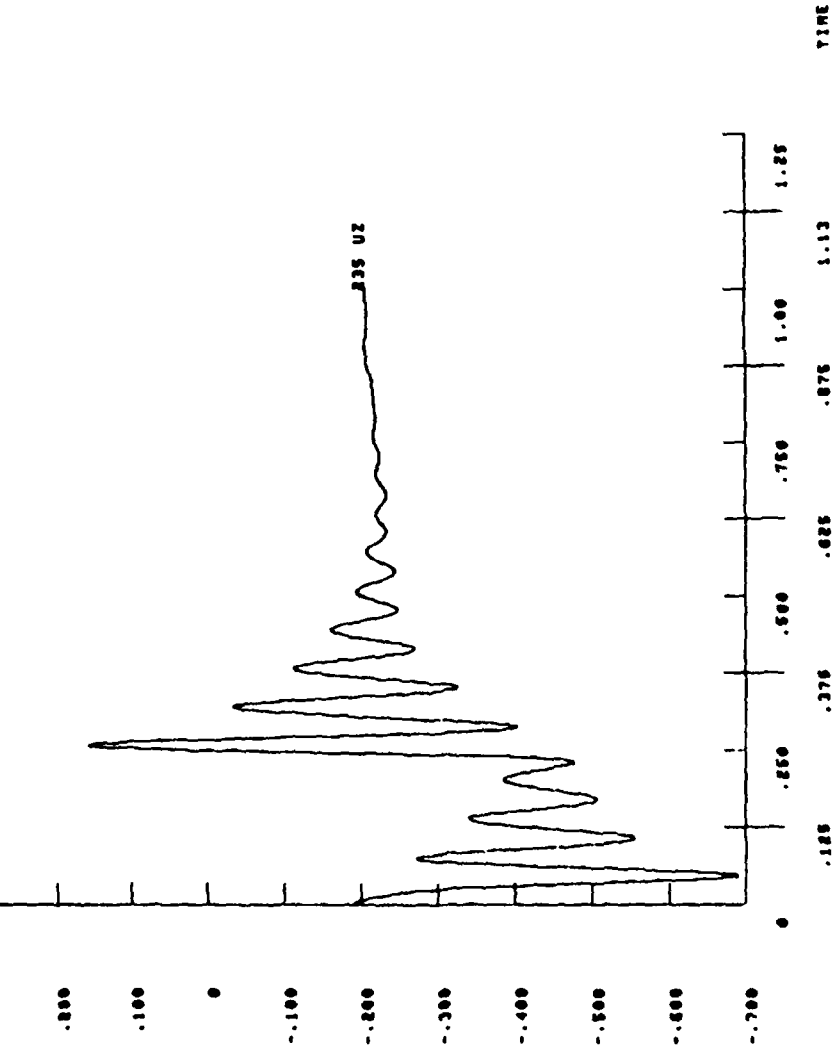
NAME



000001 COMPLETE FOR 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES
 NAME TYPE IDENTIFIED NAME MINIMUM AT TIME MAXIMUM AT TIME
 0 0100 V058 UZ 038 UZ -0.0003 0.4000E-01 0.1500 0.0000

PLOT DEFINITION
 CURVE VARIABLE NAME
 1 038 UZ



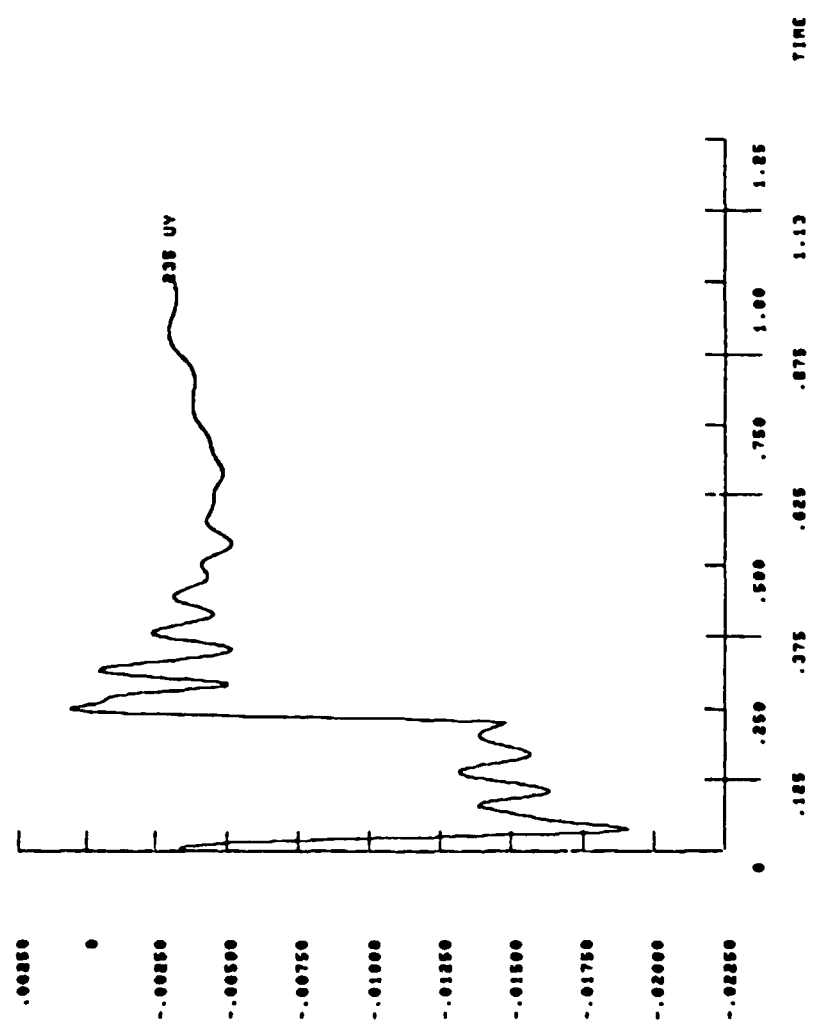
1 LUMB-0.72 CASE, PROOF LOSS-C.R.08710FF

INCOMPLETE FOR 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES
 PART TYPE IDENTIFIERS NAME MINIMUM AT TIME MAXIMUM AT TIME

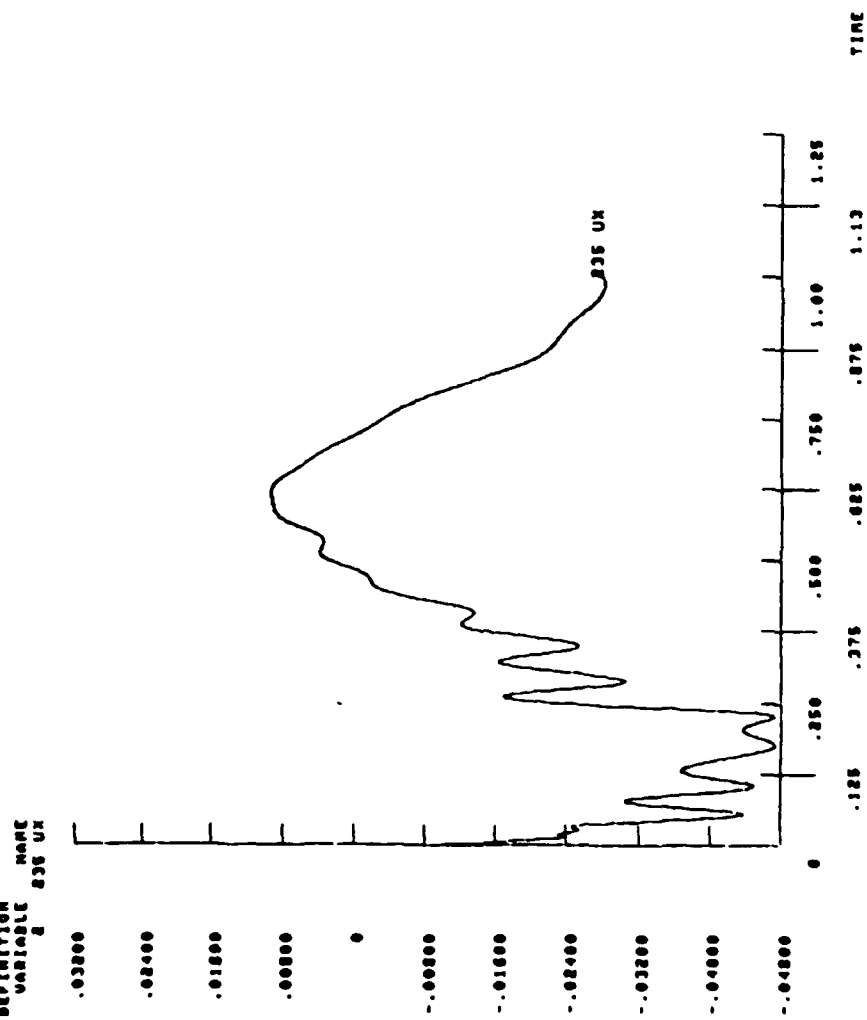
2 DISP 835 UV 835 UV -0.1808E-01 0.3800E-01 0.0806E-03 0.0400

PLOT DEFINITION
 CURVE VARIABLE 1 835 UV



1 LUMB-0.72 CASE, PROOF LOADS-C.R. ORTLOFF

| SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES | | | | | |
|--|------|-------------|------|-------------|--------------------|
| VAR# | TYPE | IDENTIFIERS | NAME | MINIMUM | AT TIME MAXIMUM |
| 8 | DISP | 235 | UX | -0.4733E-01 | 0.1760 |
| | | | | | 0.5428E-02 |
| | | | | | 0.0170 |



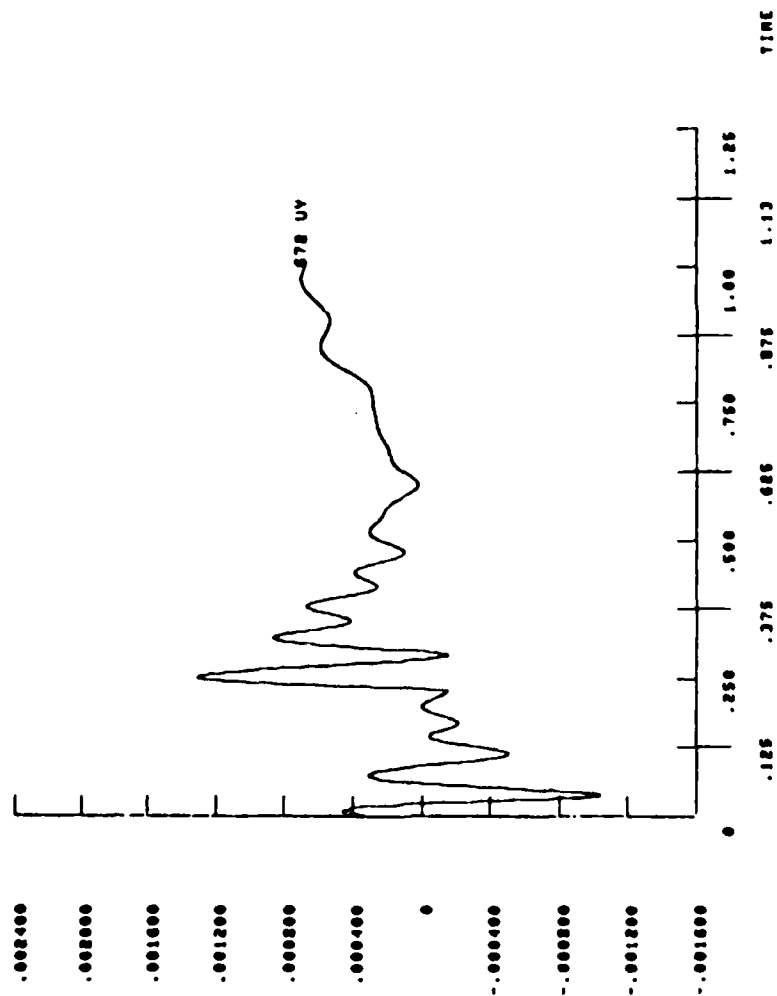
LUND-0,72 CASE, PROOF LOADS-C.N.ORTLOFF

*****COMPLETE FOR 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES
 NAME TYPE IDENTIFIERS NAME MINIMUM AT TIME MAXIMUM AT TIME

8 DISP 878 UV 878 UV -0.1040E-02 0.3700E-01 0.1300E-02 0.2510

PLOT DEFINITIONALLY
 CURVE VARIABLE NAME
 1 8 878 UV

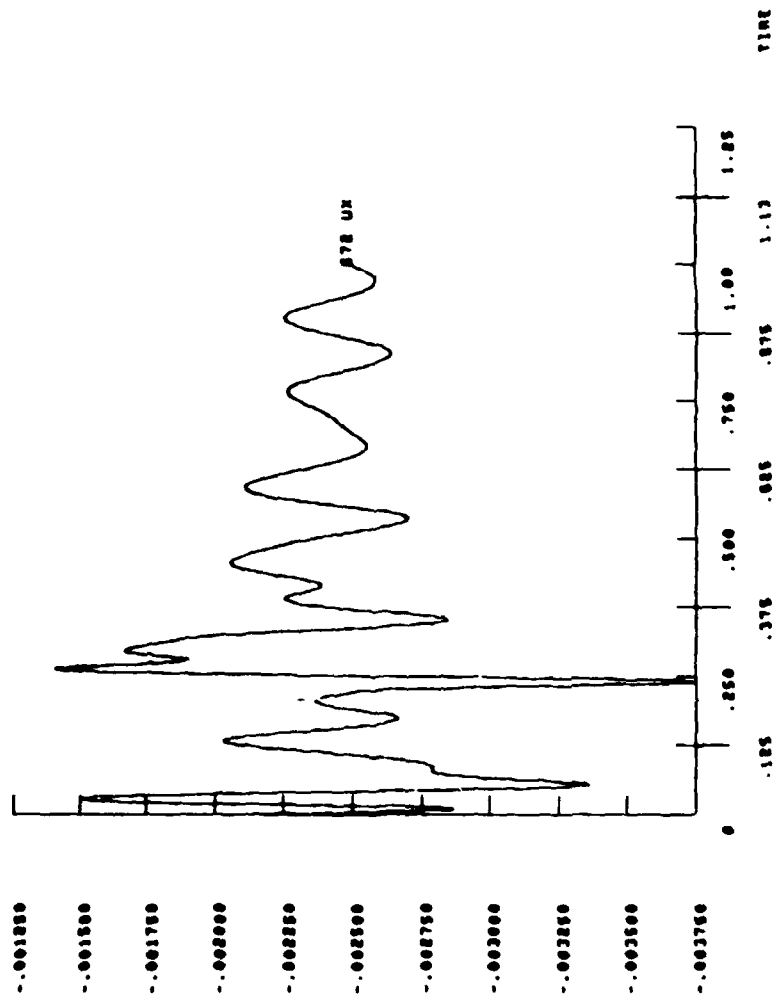


1) LUMB-0.72 CASE, PROOF LOADS-C.R. ON TLOFF

*****COMPLETE FOR 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES
 VAR1 TYPE IDENTIFIERS NAME MINIMUM AT TIME MAXIMUM AT TIME
 2 DISP 878 UN 878 UN -0.3739E-08 0.8330 -0.1407E-08 0.8830

PLOT DEFINITIONALLY
 CURVE VARIABLE NAME
 1 878 UN



1 LUMB-0.78 CASE, PROOF LOADS-C.R. 00710FF

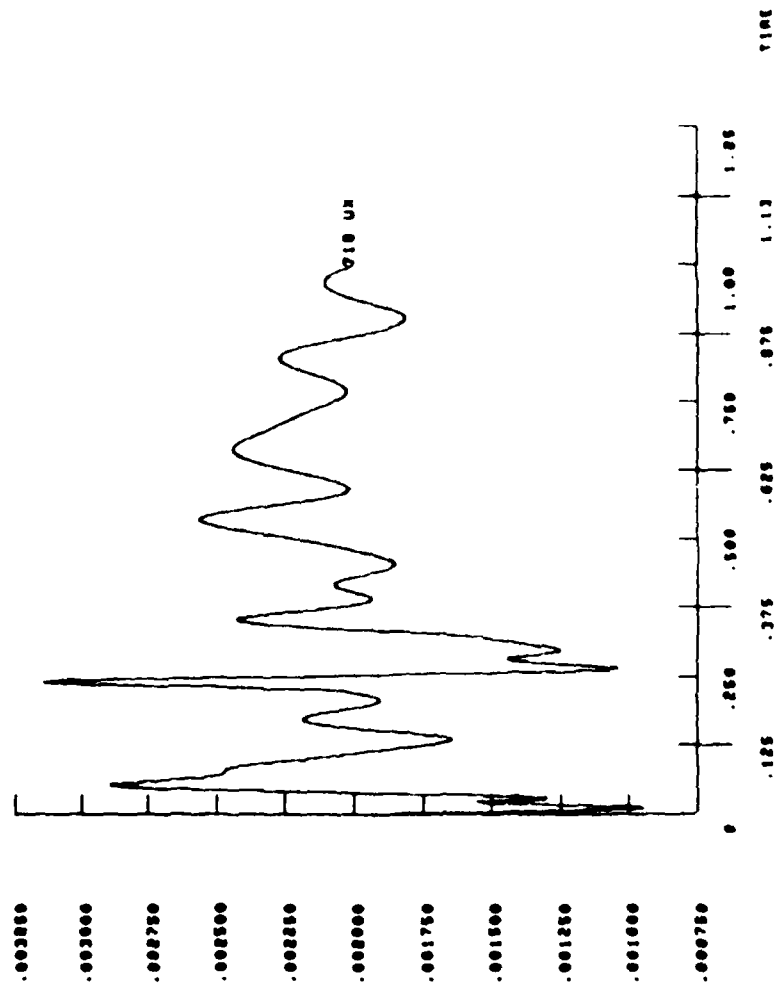
000780
 20-1

===== COMPLETE FOR 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES
 PART TYPE IDENTIFIERS NAME MINIMUM AT TIME MAXIMUM AT TIME

2 01SP 710 UN 710 UN 0.000000-03 0.100000-01 0.210000-00 0.0000

PLOT DEFINITIONALLY
 CURVE VARIABLE NAME
 1 0 710 UN



LUND-0.72 CASE, PROOF LOADS-C.B. ONTLOFF

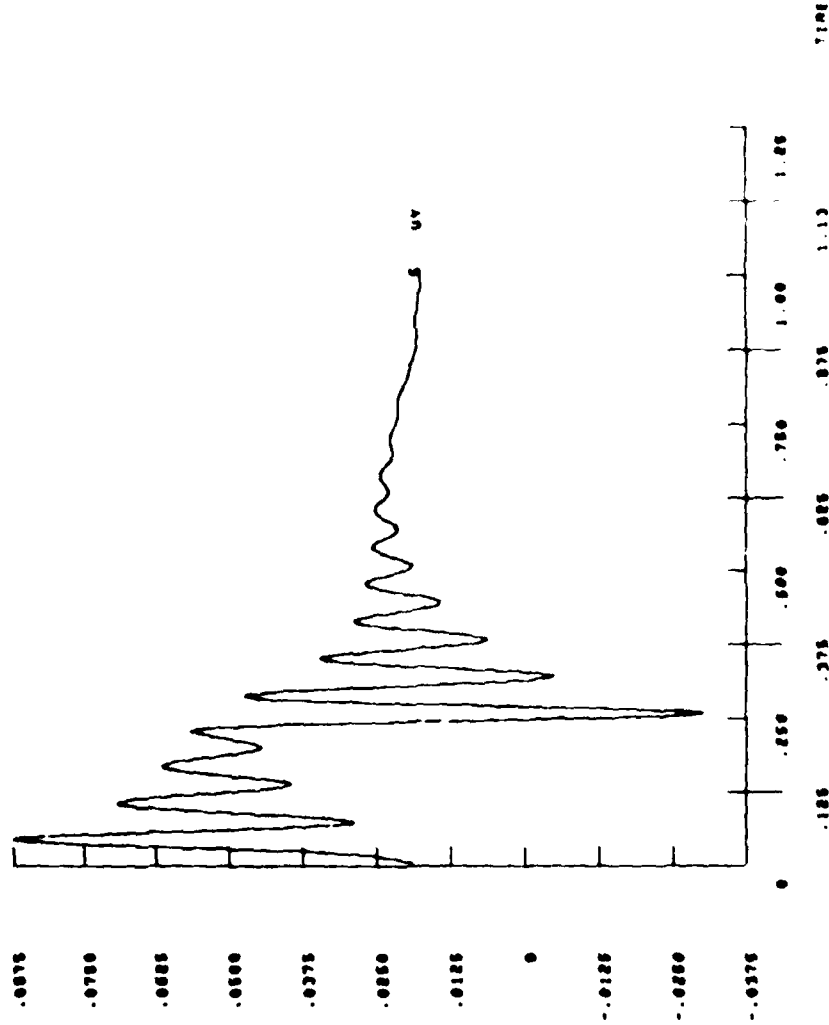
000700
 20-1
 0187-1.00

===== COMPLETE FOR 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES
 NAME TYPE IDENTIFIERS NAME MINIMUM AT TIME MAXIMUM AT TIME

A STEP WAVE UV S UV -0.3037E-01 0.2500 0.0740E-01 0.0000E-01

=====
 PLOT DESCRIPTION
 CURVE VARIABLE NAME



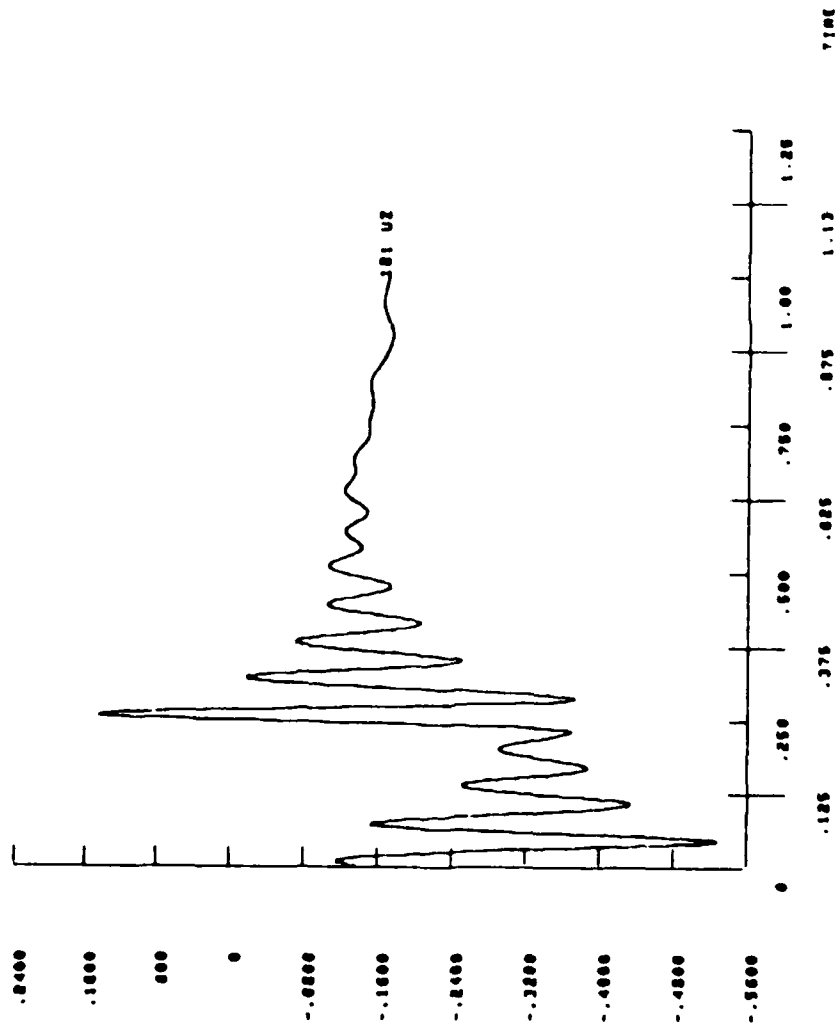
=====

POSTJOB
 20-1
 0107-1 03

*****COMPLETE FOR 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES
 NAME IDENTIFIERS NAME MINIMUM AT TIME MAXIMUM AT TIME
 0 0100 VALU UZ 101 UZ -0.5000 0.00000E+01 0.1402 0.0000

PLOT DEFINITION
 CURVE VARIABLE NAME
 1 101 UZ



1 LUMP-0.72 CASE, PROOF LOADS-C.R.00TLOFF

003706
 20-1
 0107-1.43

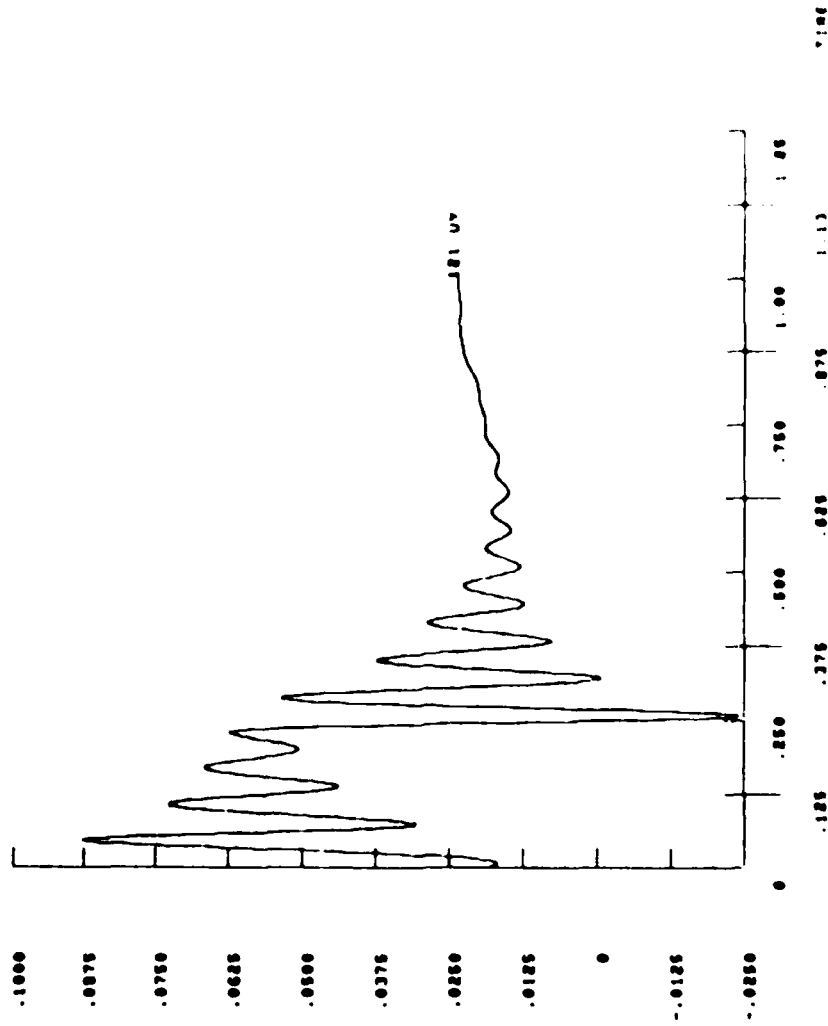
PROGRAM COMPLETE FOR 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTENDING VALUES

VAR1 TYPE IDENTIFIERS NAME MINIMUM AT TIME MAXIMUM AT TIME

2 DISP WAVE UV 181 UV -0.2418E-01 0.0000 0.0701E-01 0.4000E-01

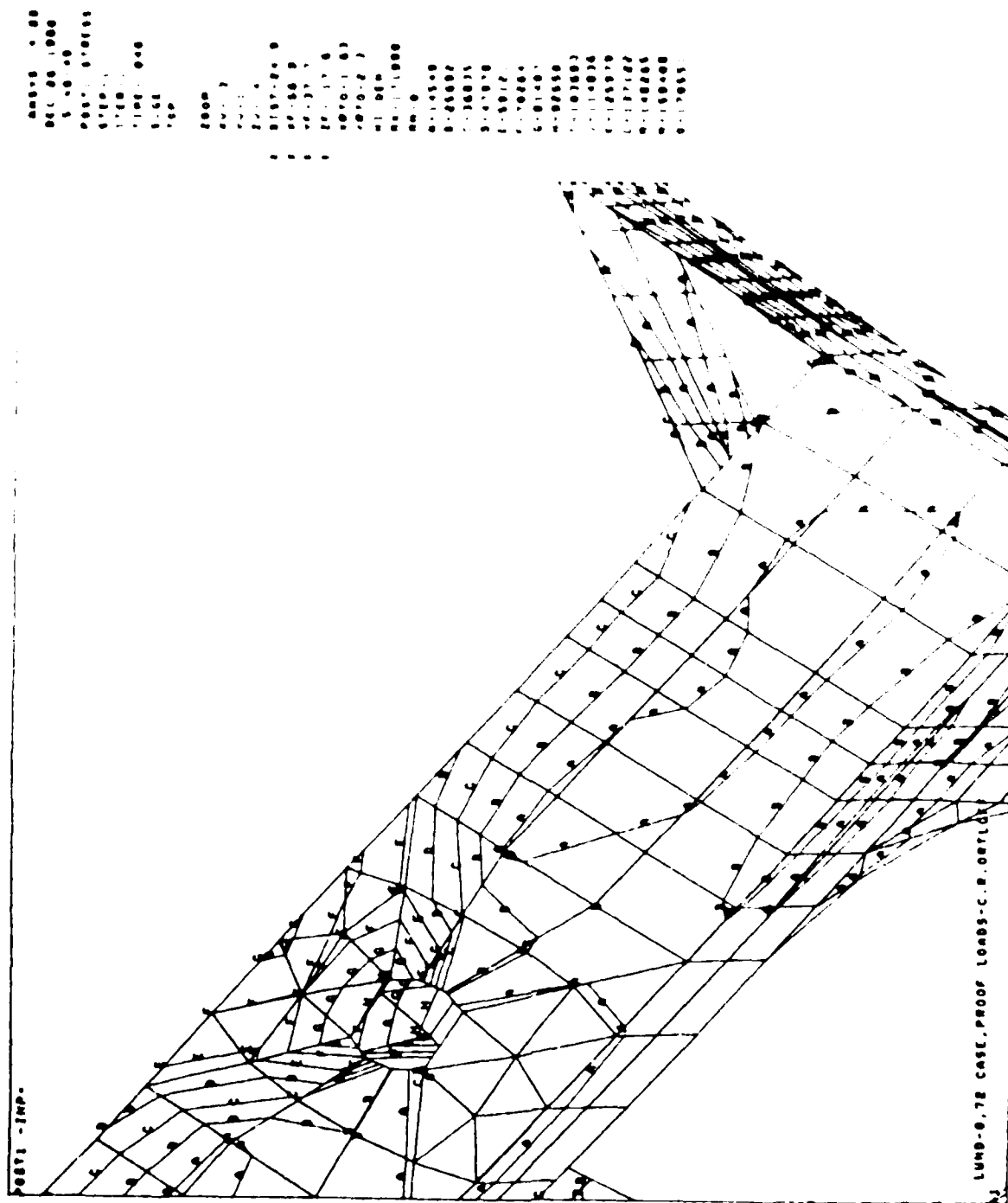
PLOT DEFINITION
CURVE VARIABLE NAME
181 UV

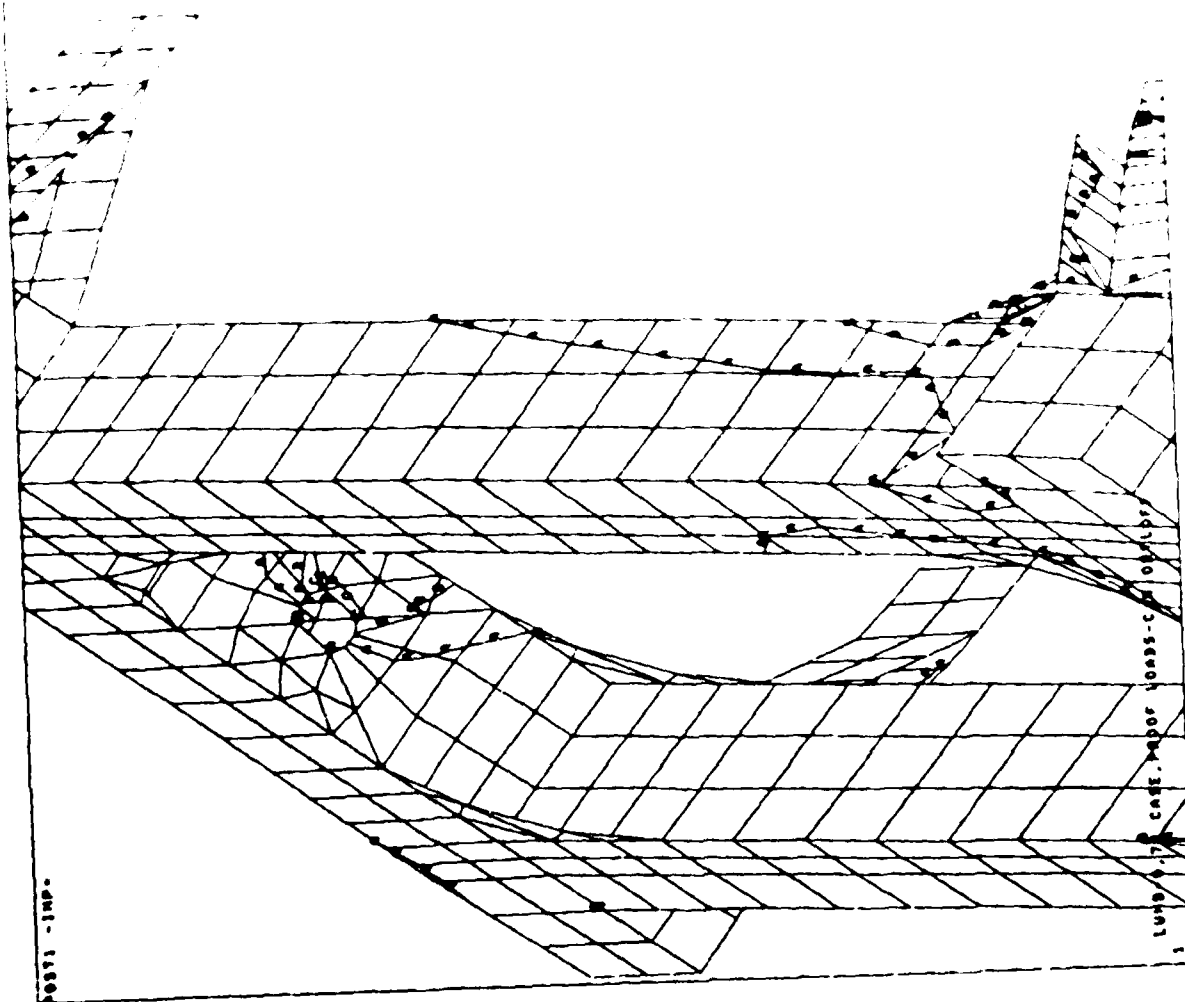


1 LUMB-0.72 CASE, PROOF LOADS-C.M.0271077

POSTED
7-1
8107-1 43

•



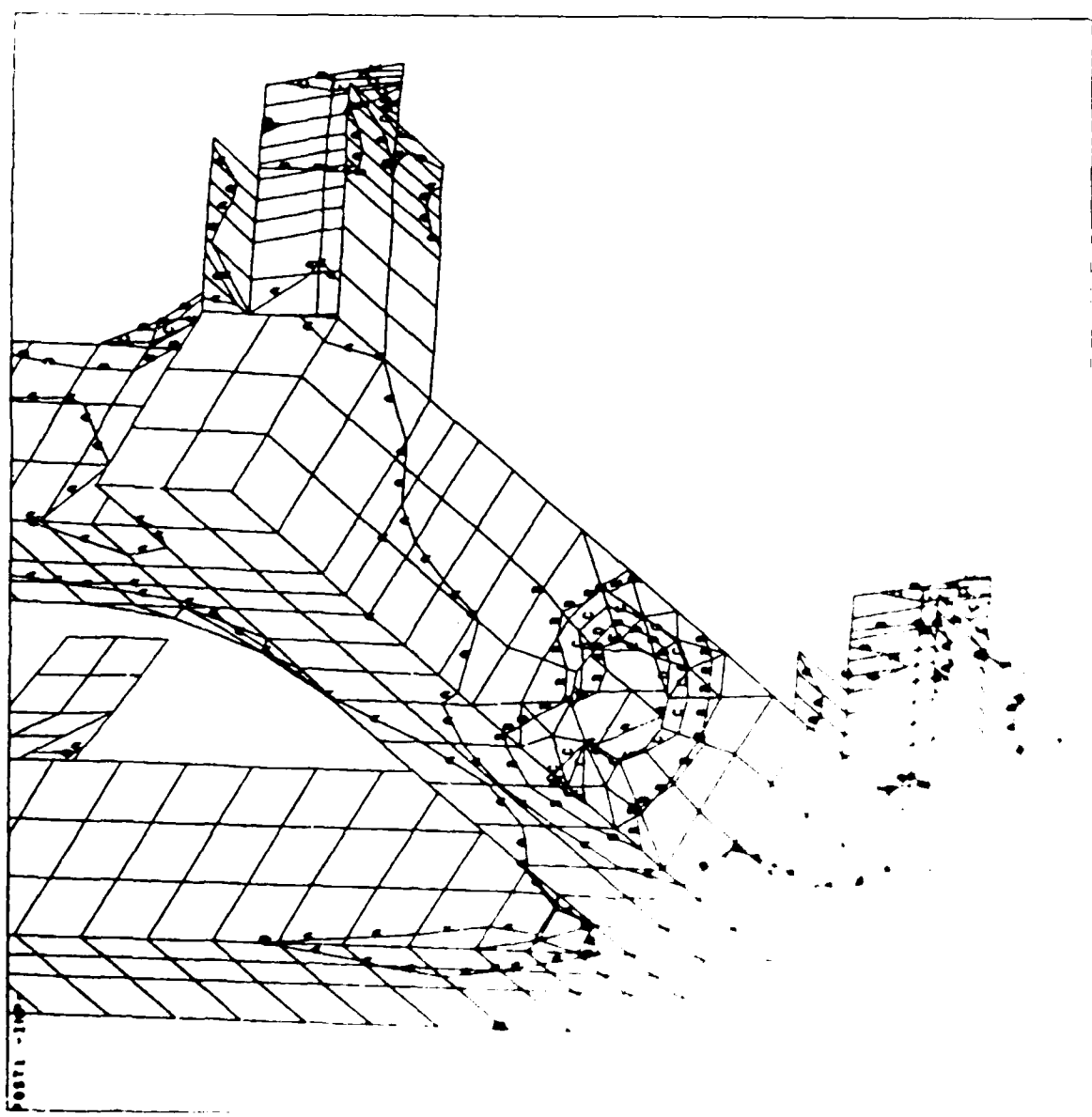
[illegible]

LUND-0,72 CASE, PROOF LOADS-C.R. ORTLOFF

```

ANALY 1.00
SEC 26 1000
15-11-00
POST1 STRSS
STEP=1
TYPE=1
TIME=0.45
SLC=
TOP
ZOOM
ZU=1
VU=1
ZU=1
VU=1
B157-20.8
B 25-45.8
B 25-21.7
B 25-15.1
KOTO-1.45
KOTO-1.80
MIDDEH
MM-181693
MM-8
A-33180
B-62835
C-92580
D-122265
E-151980

```



AD-A183 993

LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR PHASE 1 AND
PARTIAL PHASE 2 VOLUM (U) FMC CORP MINNEAPOLIS MINN
NORTHERN ORDNANCE DIV R RATHE ET AL APR 87

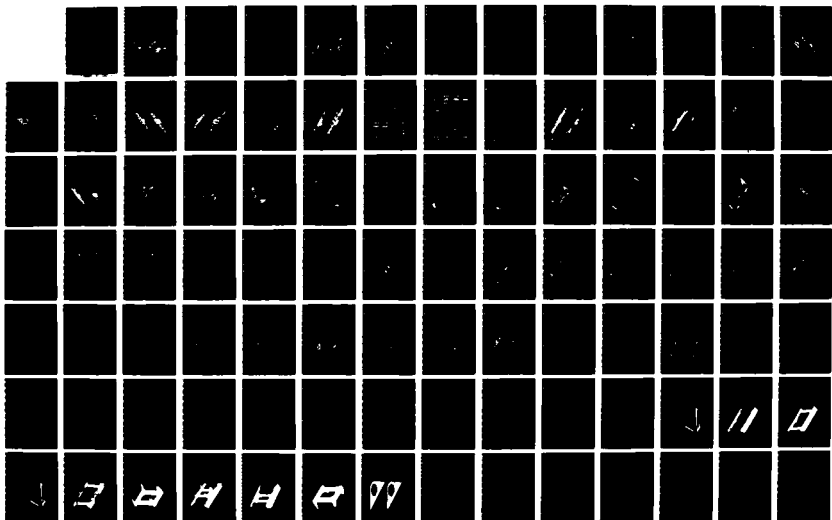
3/5

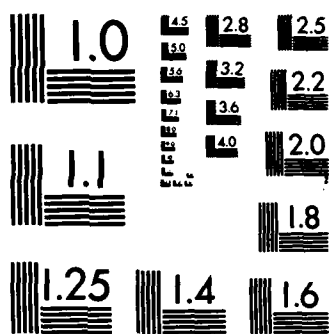
UNCLASSIFIED

FMC-E-3041-VOL-D3-PT-1 DAAA21-86-C-0047

F/G 19/6

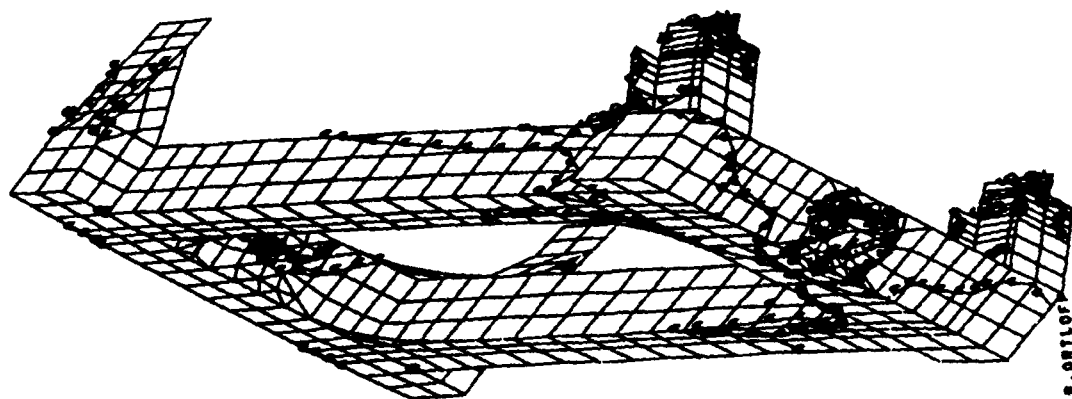
NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

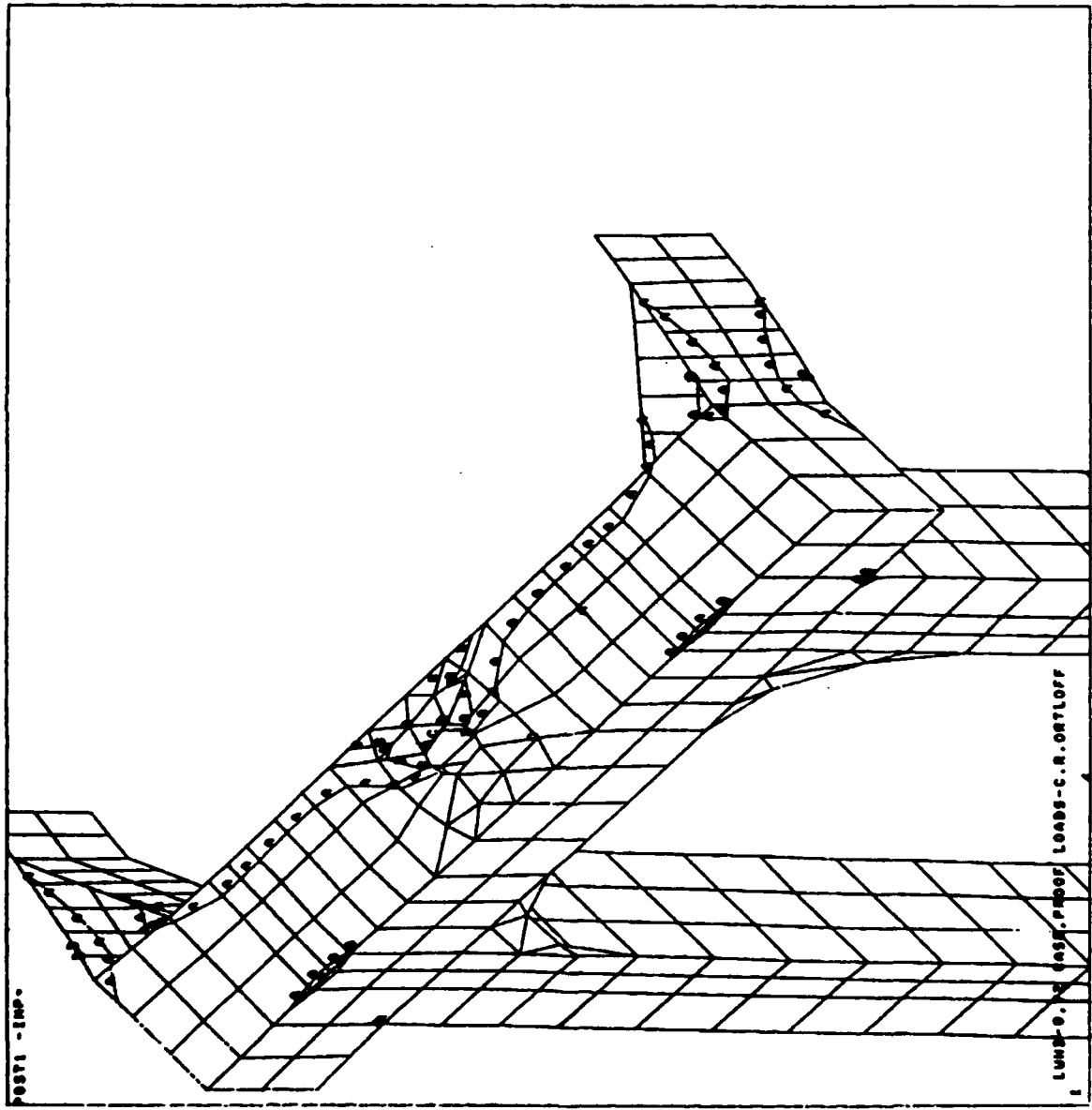
ANSYS 4.84
 DEC 26 1986
 16131120
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.046
 SICE
 TOP
 ZOOM
 RV=1
 VU=-1
 ZU=.7
 DIST=84
 KP=54.7
 VF=35
 ZF=-8.78
 VRTQ=1.89
 MI99EN
 MX=181693
 MN=3408
 A=33120
 B=82825
 C=92556
 D=122265
 E=151980



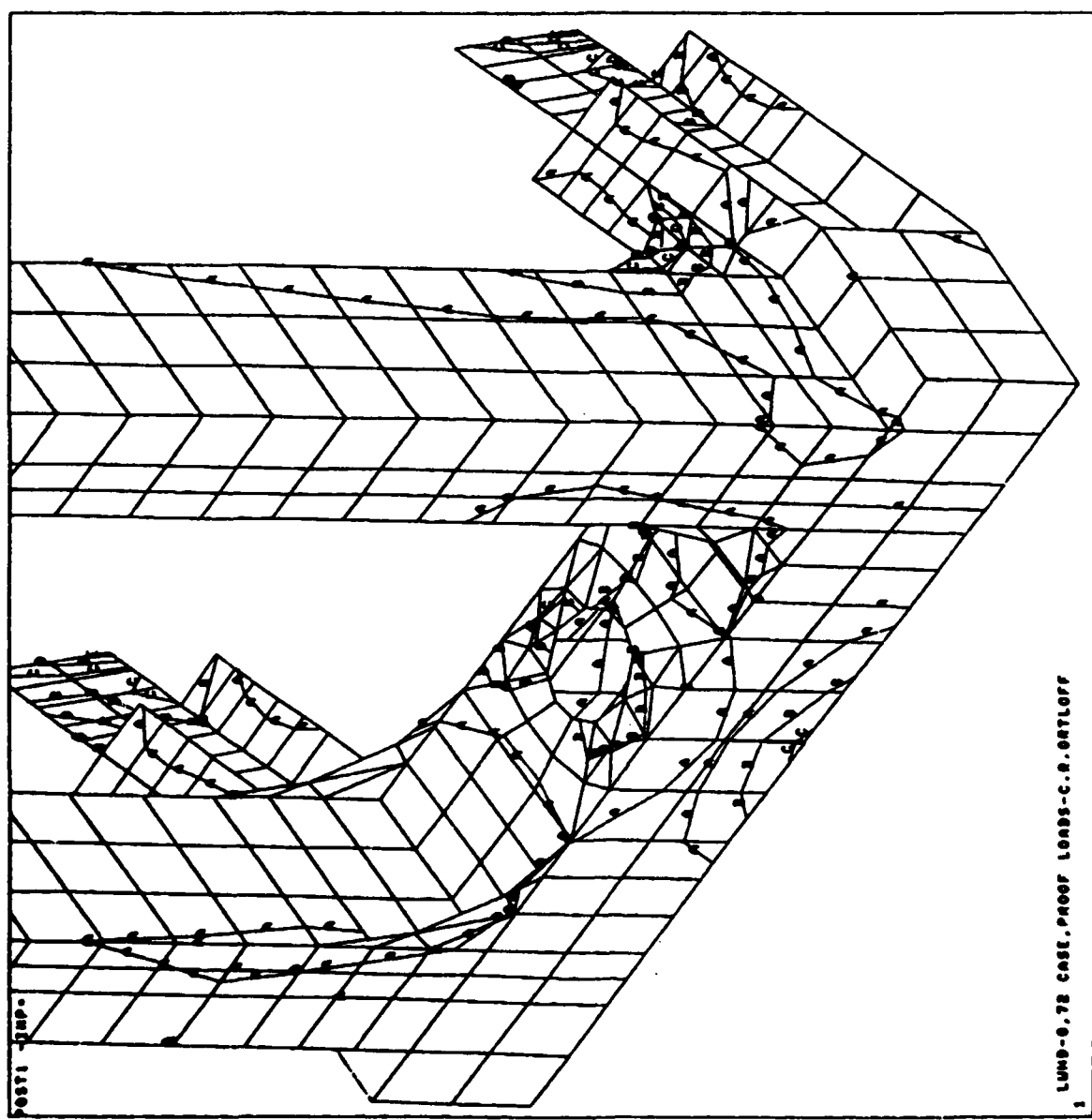
POST1 -IMP.
 ZOOM

LUNB=0.72 CASE,PROOF LOADS-C.R.ORTLOF

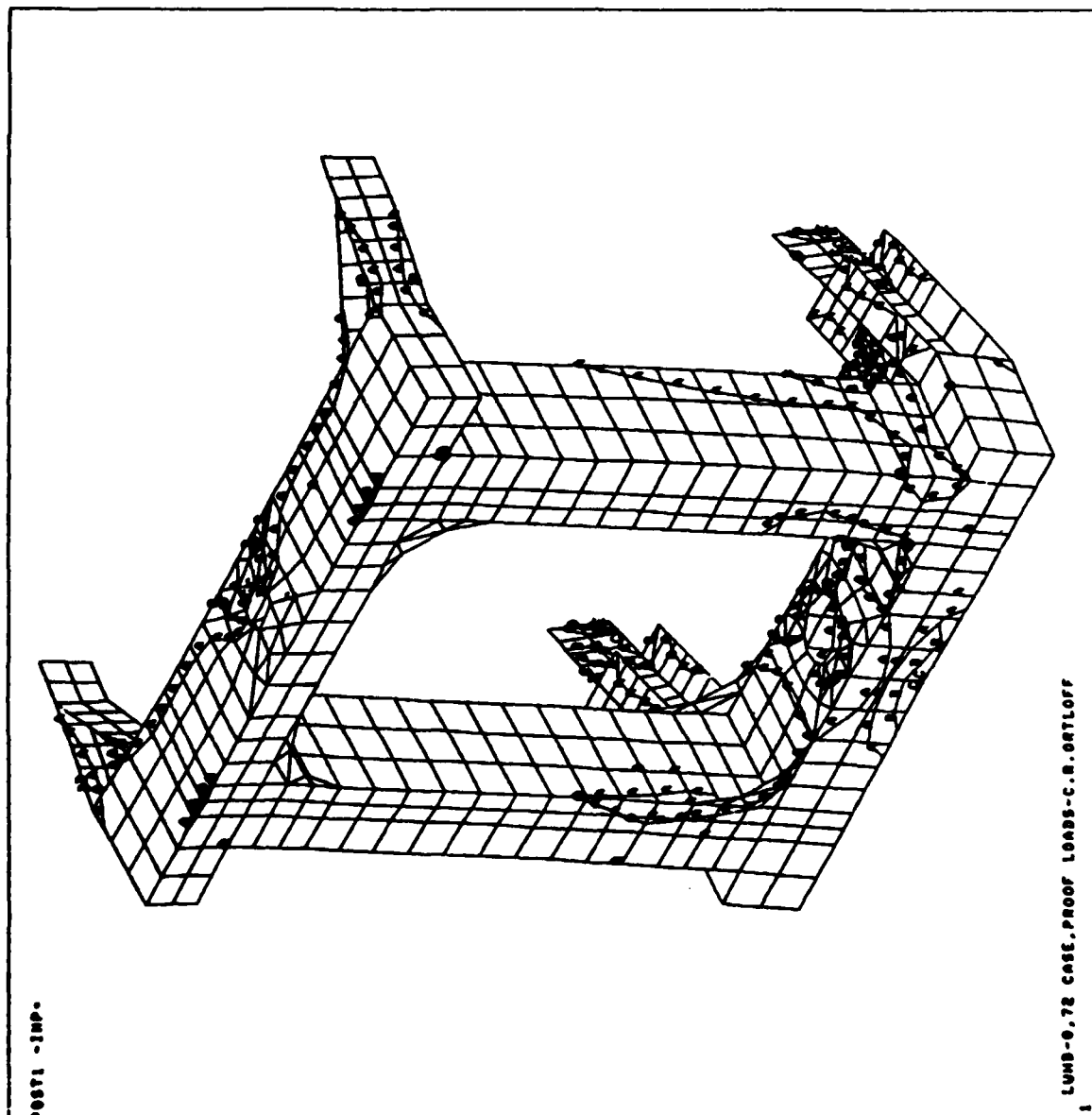
ANSYS 4.28
 DEC 26 1986
 15123110
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.045
 SICE
 TOP
 ZOOM
 KU=1
 VU=1
 2U=1
 2 8157-20.6
 3 XF=54
 3 VF=46.7
 3 ZF=19.9
 VRT0=1.89
 HIDDEN
 RX=131137
 RM=6
 A=23120
 B=62835
 C=92550
 D=122255



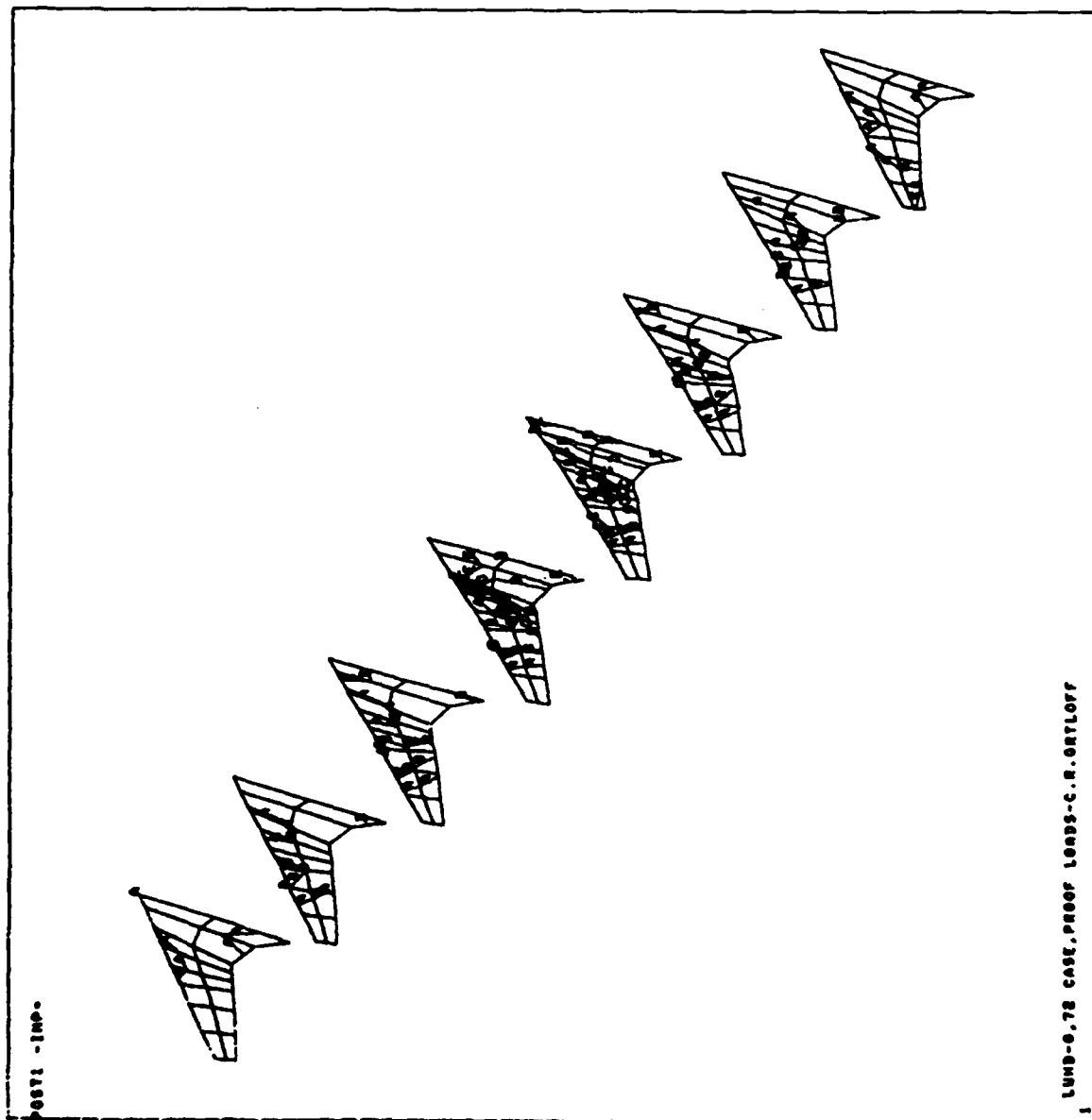
ANSYS 4.20
 DEC 26 1986
 15:10:14
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.046
 SIQE
 TOP
 ZOOM
 XZ=1
 YZ=1
 ZU=1
 Z DIST=21.4
 Z XF=61
 Z VF=21.1
 Z ZF=-1.34
 VRTD=1.33
 HIDDEN
 RM=101803
 RM=0
 A=33120
 B=62835
 C=92550
 D=122265
 E=151980



ANSYS 4.20
 DEC 26 1986
 1519114
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.046
 SLOC
 TOP
 20=1
 20=1
 20=1
 2187-34.2
 27-54.9
 27-32.9
 27-5.01
 HIDDEN
 MM-101093
 MM-3406
 0-33120
 0-62026
 C-92550
 D-122265
 E-151000



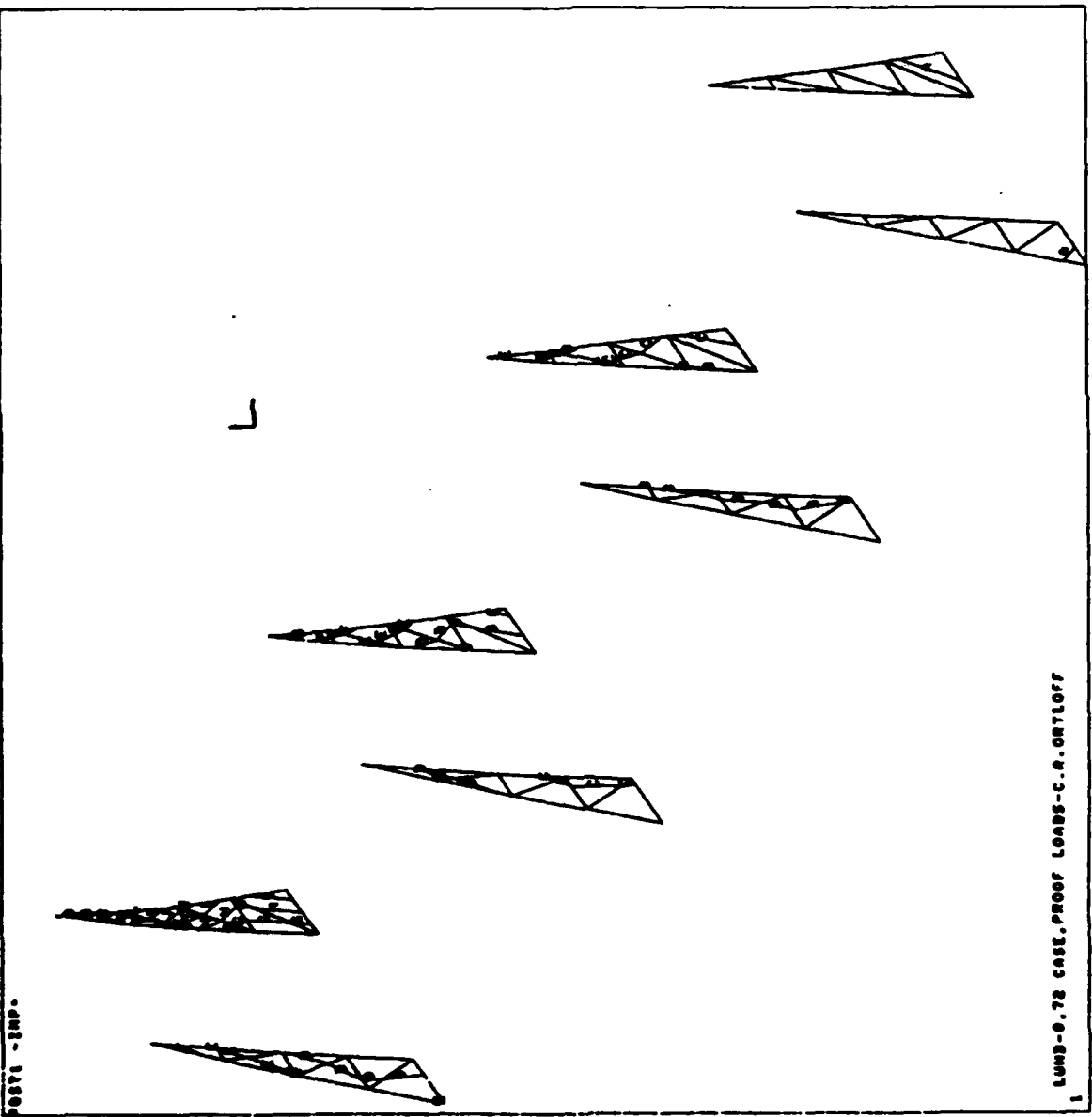
ANSYS 4.08
 DEC 26 1986
 15115184
 POST1, STRESS
 STEP=1
 LTEMP=1
 TIME=.046
 SIZE
 TOP
 ZOOM
 NU=1
 VU=1
 ZU=1
 DIST=63.8
 XF=52.3
 YF=-1.67
 ZF=5.33
 WRT0=1.3
 WRT0=1.02
 HIDDEN
 MX=33779
 MY=528
 A=6070
 B=11612
 C=17154
 D=22696
 E=28238



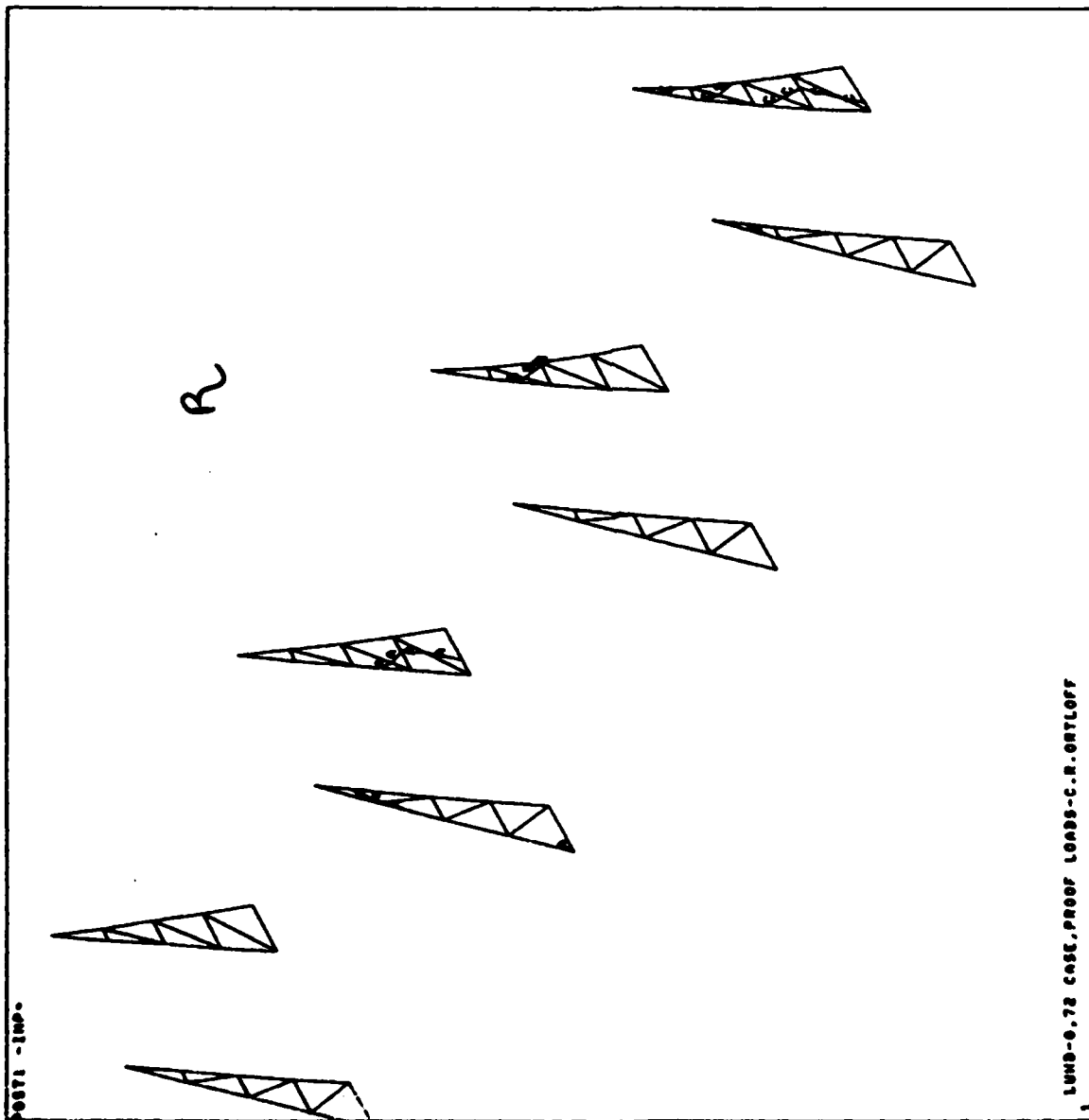
POST1 -IMP-

LUND-0.72 CASE,PROOF LOADS-C.R.ORTLOFF

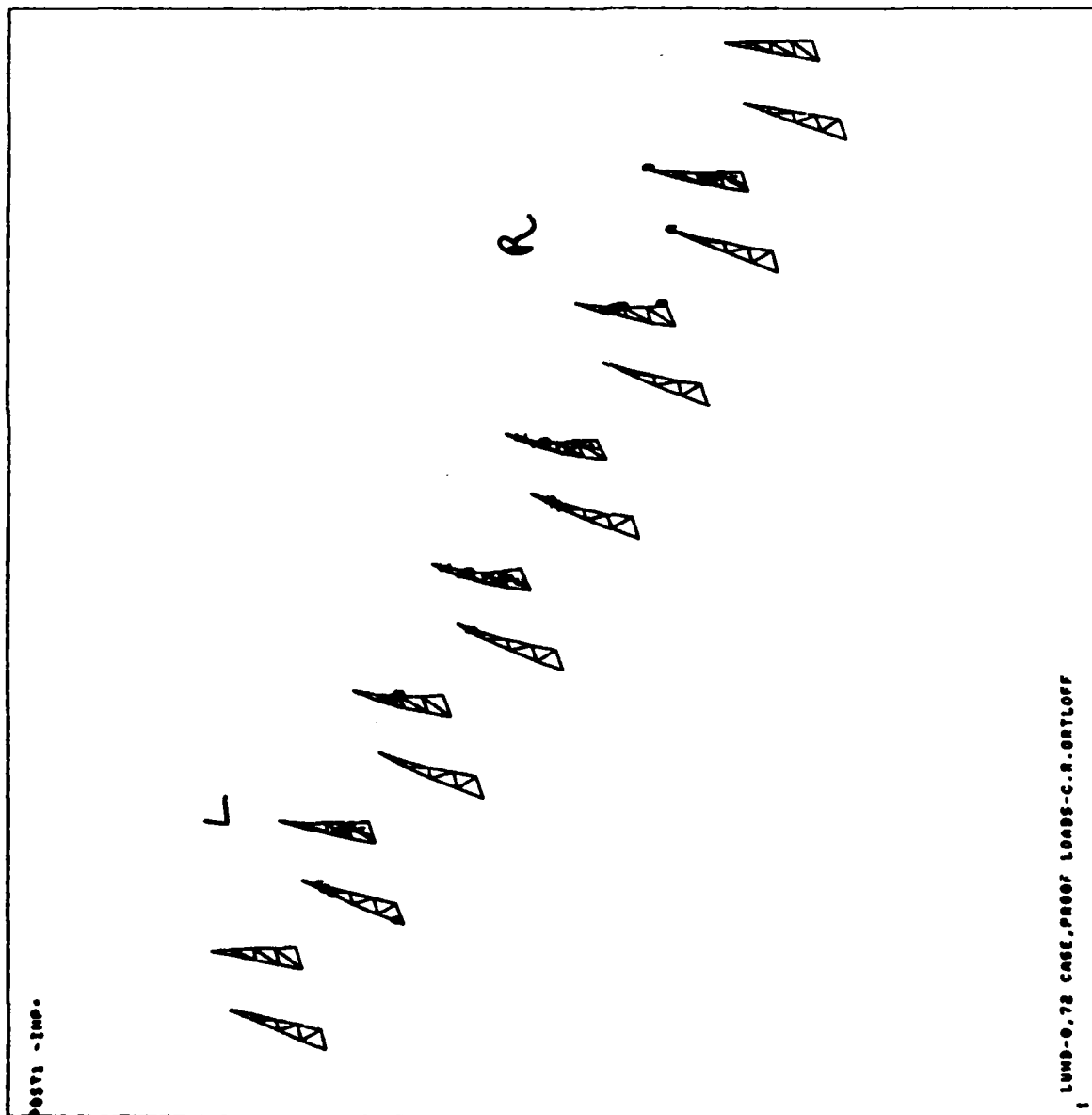
ANSYS 4.28
 DEC 26 1988
 18114139
 POST1 STRSS
 STEP=1
 TYPE=1
 TIME=.048
 SIZE
 TOP
 ZOOM
 KU=1
 VU=1
 ZV=1
 2 0161-28
 3 1F-73.8
 4 1F-5.39
 5 2F--8.11
 6 1870-1.3
 7 1870-1.82
 8 HIDDEN
 9 H1-86033
 10 H1-1888
 11 A-5863
 12 D-11141
 13 C-16419
 14 D-21897
 15 E-26975
 16 F-32853
 17 G-37521
 18 H-42809
 19 I-48087
 20 J-53365
 21 K-58643
 22 L-63821
 23 M-69195
 24 N-74477
 25 O-79755



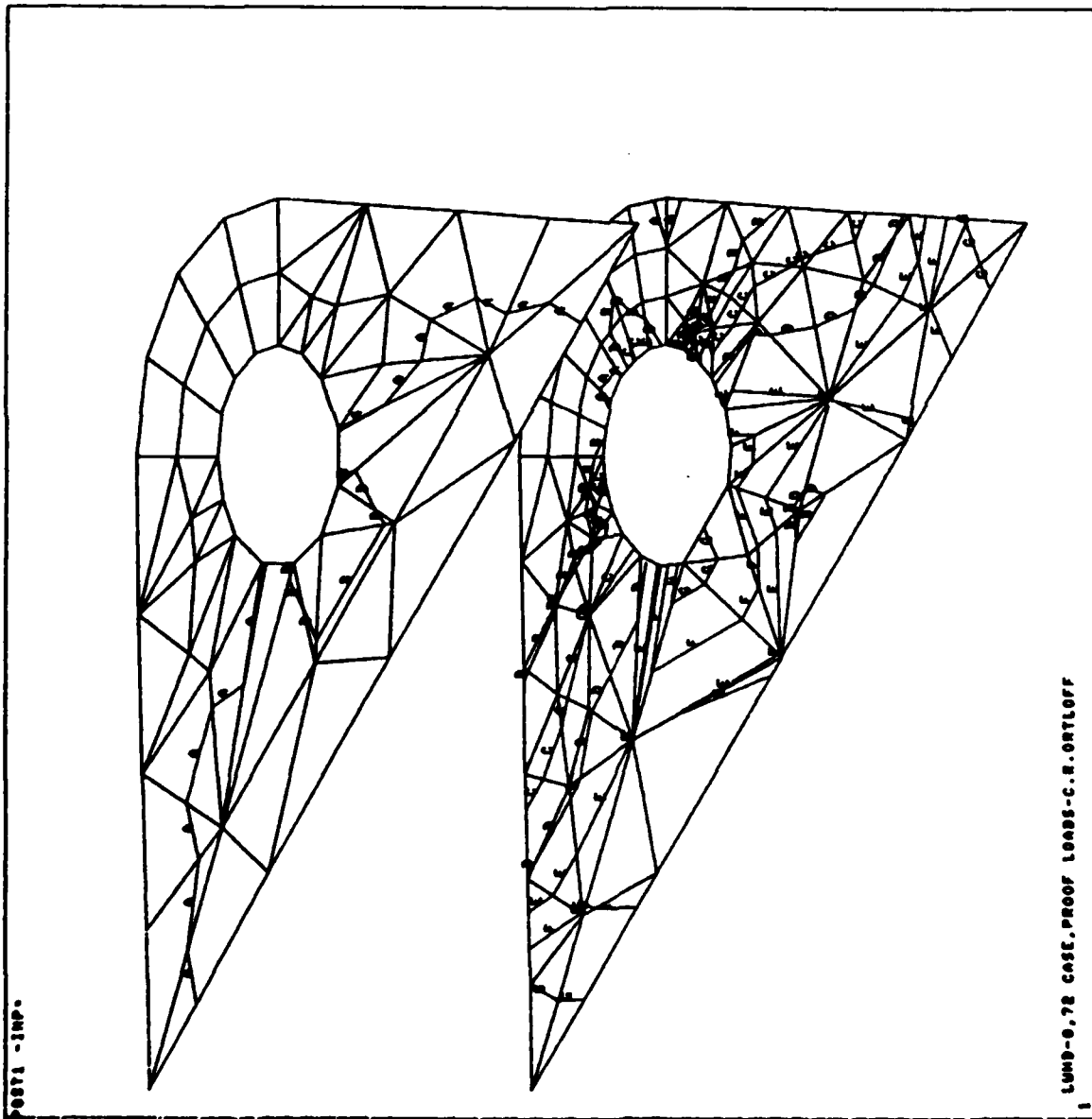
ANSYS 4.2B
 DEC 26 1988
 15:12:59
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.046
 SIDE
 TOP
 ZOOM
 XU=1
 YU=1
 ZU=1
 2 DIST=27.4
 2 KF=34
 2 VF=13
 2 ZF=12.6
 KATO=1.2
 VATO=1.56
 MIDDLE
 RK=2337
 RM=585
 A=14658
 B=28734
 C=42808
 D=56884
 E=70858



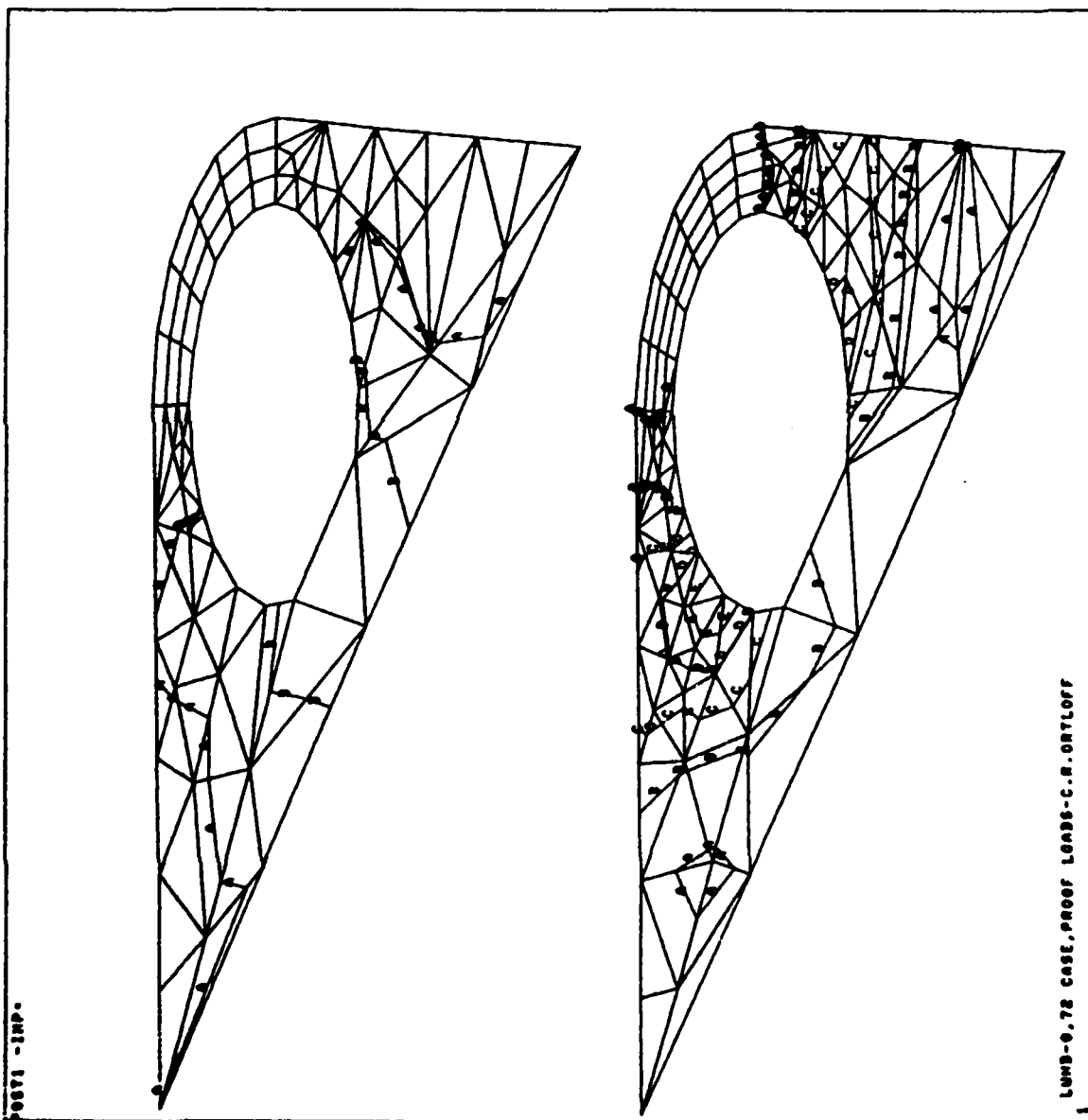
ANSYS 4.20
 DEC 26 1986
 15:18:59
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.046
 SICE
 TOP
 ZOOM
 XU=1
 YU=1
 ZU=1
 DIST=59.7
 WF=62.8
 VP=3.85
 ZP=3.3
 XRT0=1.3
 YRT0=1.29
 MIDDEN
 RX=88033
 MY=585
 A=14850
 B=20724
 C=42809
 D=56204
 E=70950



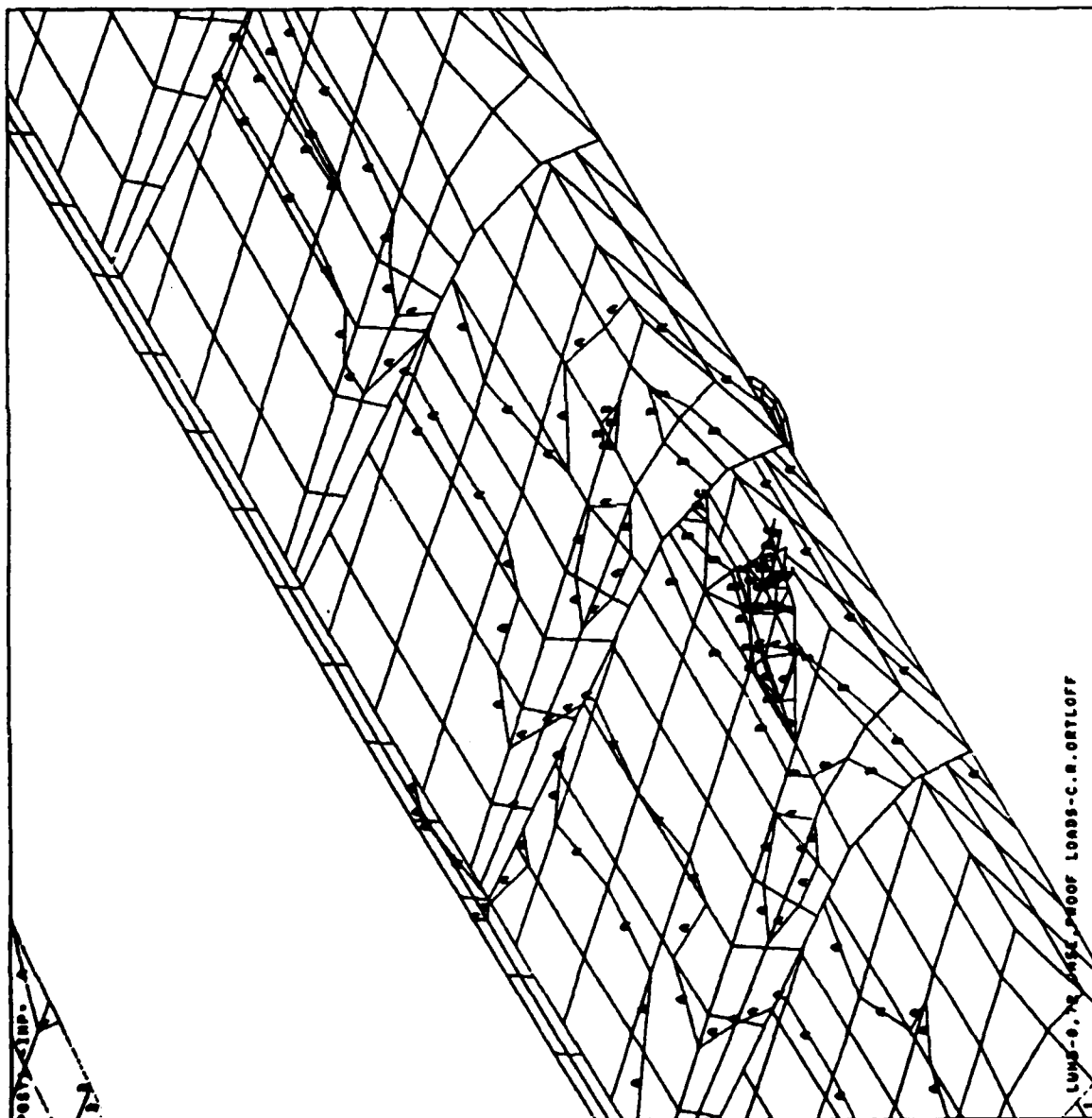
ANSYS 4.20
 DEC 26 1986
 15110157
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.046
 SLOC
 TOP
 ZOOM
 KU=1
 VU=1
 ZU=1
 DIST=8.08
 XF=44.3
 VF=88.8
 ZF=-11
 KATO=1.3
 VATO=1.29
 M100EM
 MX=28576
 MY=1803
 A=4367
 B=7833
 C=11209
 D=14765
 E=18231
 F=21697
 G=25163



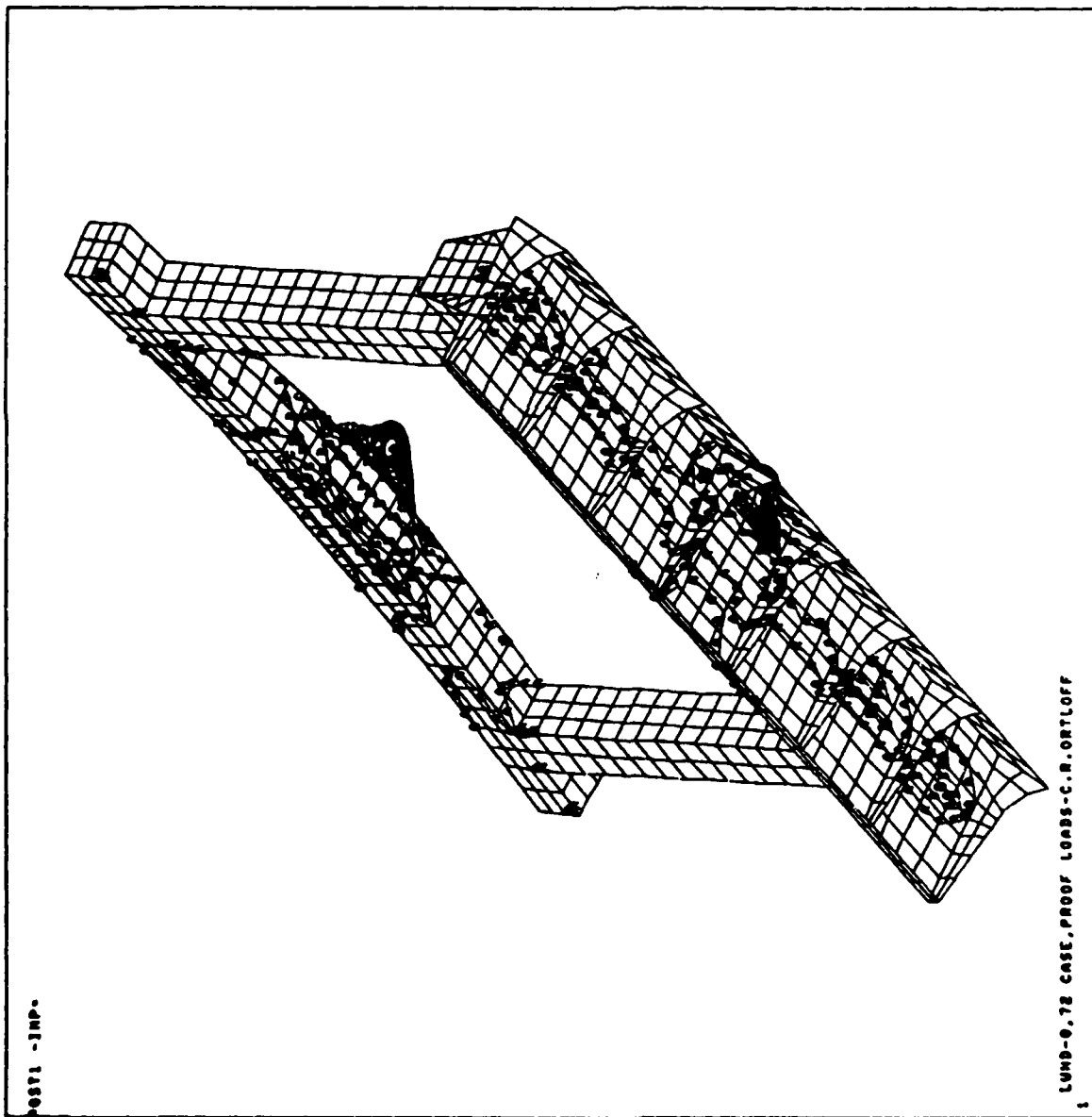
ANSYS 4.20
 DEC 26 1986
 15:09:30
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.046
 SLOC
 TOP
 ZOOM
 X0=1
 Y0=1
 Z0=1
 * DLIST=8,68
 * KP=62.1
 * VP=14.1
 * ZF=8.97
 XRT0=1.3
 HIDDEN
 MM=56356
 MM=803
 A=10143
 B=19386
 C=28629
 D=37872
 E=47115



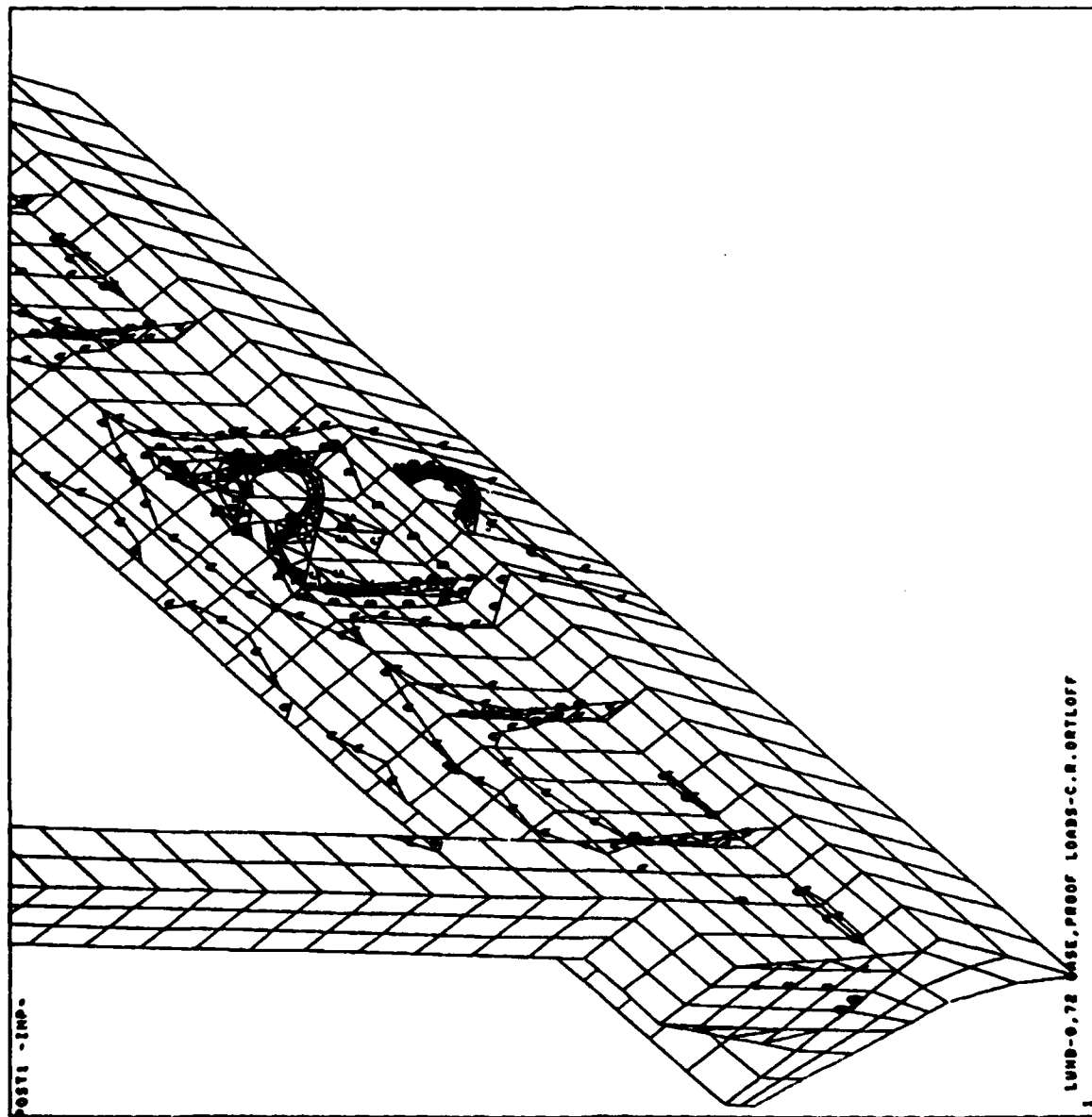
ANSYS 4.20
 DEC 26 1986
 14145107
 POST1 STRESS
 STEP=1
 ITEM=1
 TIME=.046
 SECT
 TOP
 ZOOM
 XU=1
 VU=-1
 ZU=.7
 2 8197-23.6
 2 XF-46.7
 2 VF-14.8
 2 ZF-5.61
 XRT0=1.49
 HIDDEN
 RX=67985
 RM=0
 A=11896
 B=23114
 C=34332
 D=45550
 E=56768

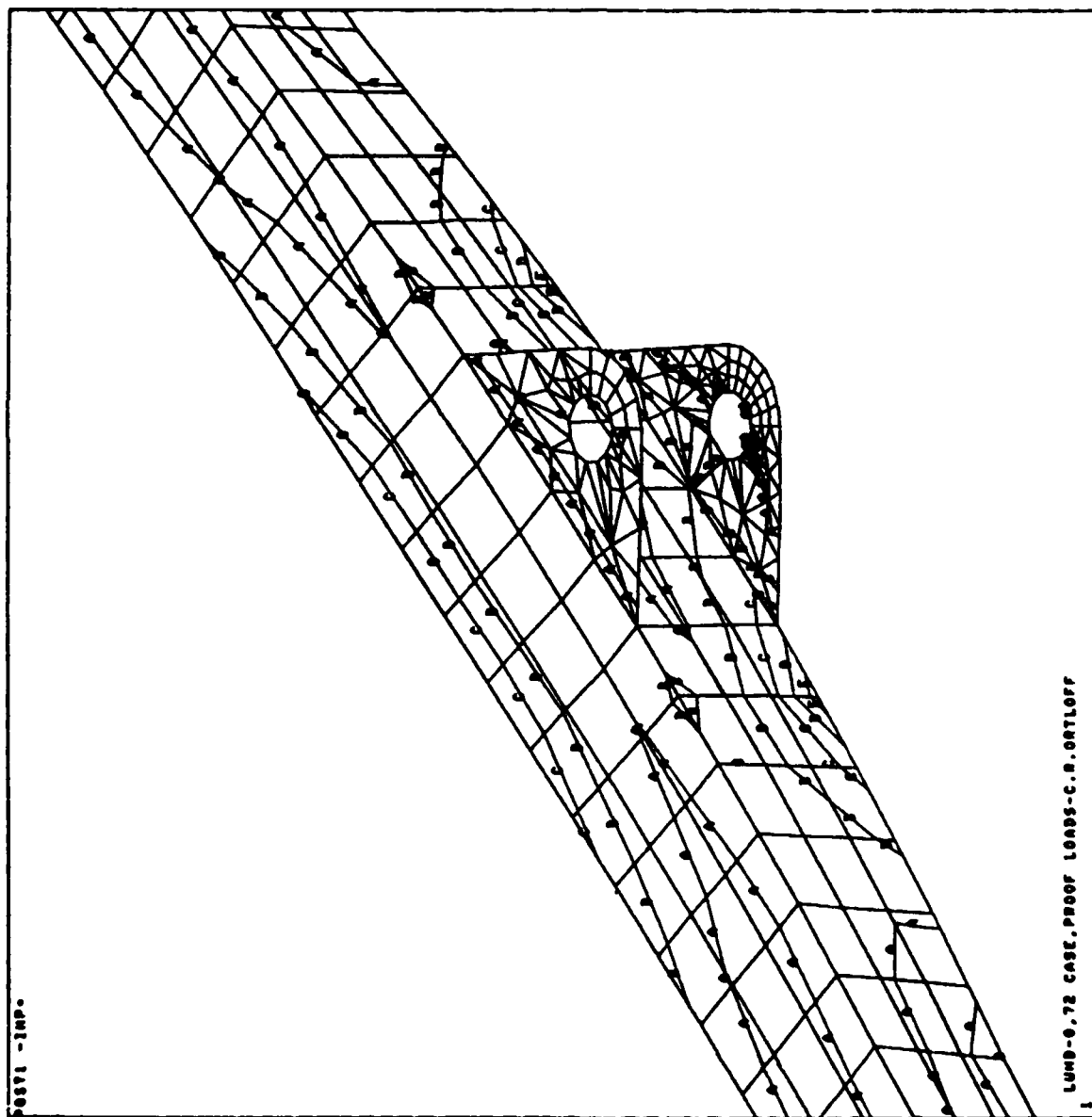


ANSYS 4.20
 DEC 26 1986
 14145107
 HOST1 STRESS
 STEP=1
 ITER=1
 TIME=.046
 SIZE
 TOP
 NU=1
 VU=-1
 ZU=.7
 2 3197-68.7
 2 37-51.4
 2 37-26.9
 2 27-4.88
 MIDDEN
 RM-6788
 RM-680
 A-11896
 B-23114
 C-24332
 D-46550
 E-56768



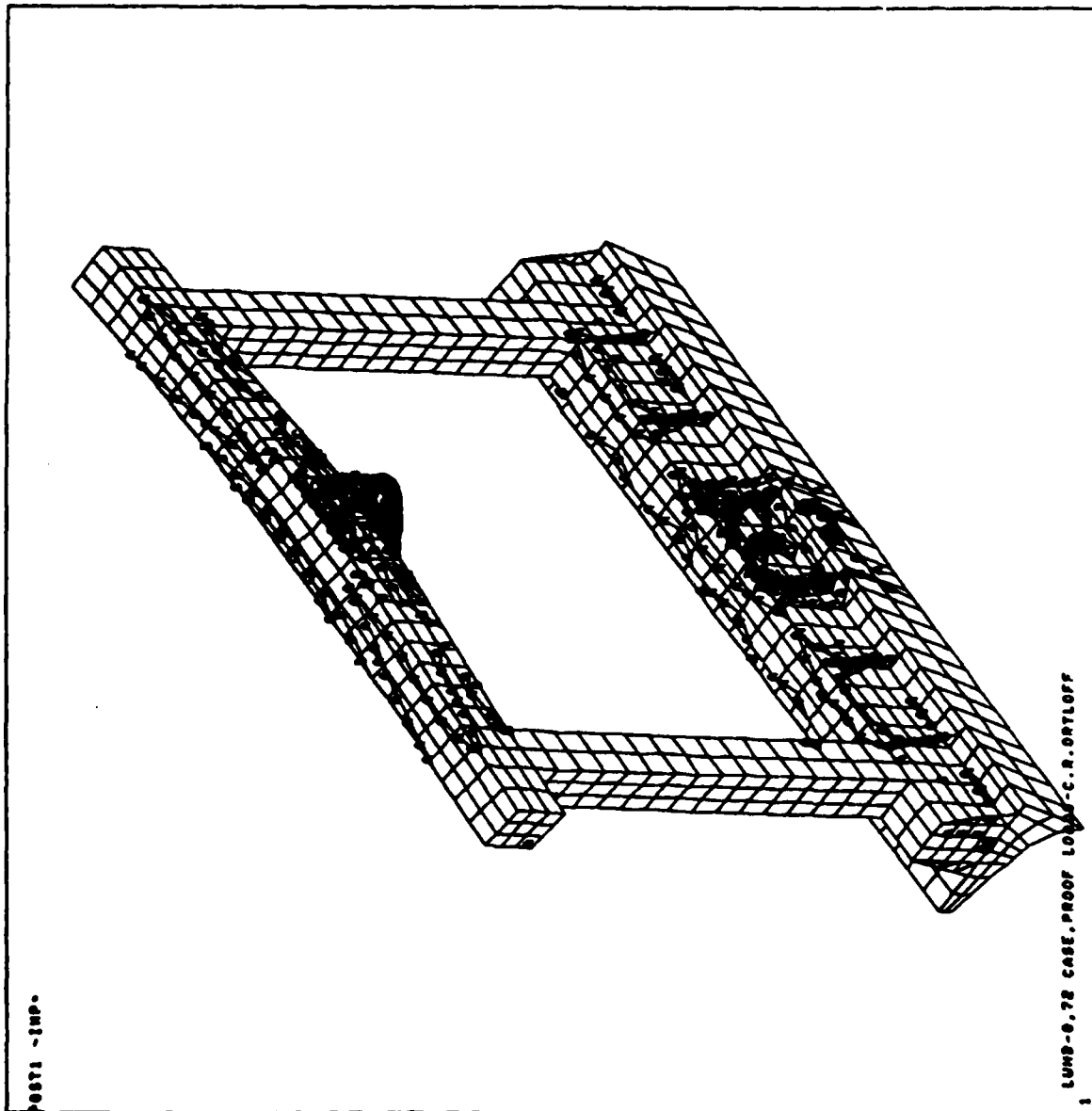
ANSYS 4.20
 DEC 26 1986
 14120150
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.046
 SIZE
 TOP
 ZOOM
 XU=1
 VU=1
 ZU=-1
 Z 2187.65.4
 Z KF=65.3
 Z VF=1.50
 Z ZF=-8.84
 XRT0=1.18
 VRT0=2.38
 HIDDEN
 RK=67985
 RM=0
 A=11896
 B=23114
 C=34332
 D=45550
 E=56768



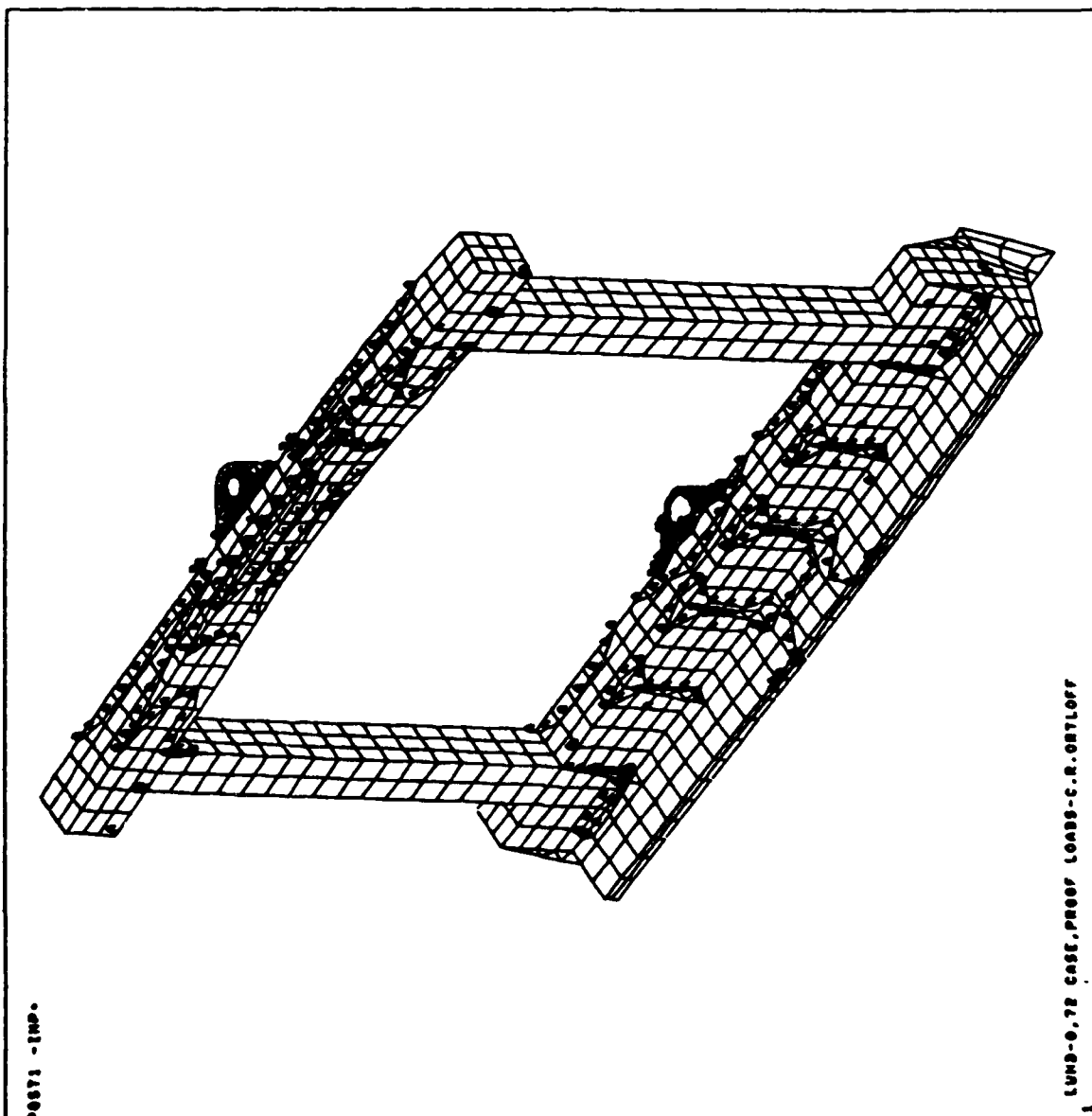


LUND-0,72 CASE, PROOF LOADS-C.N. OYTLÖFF

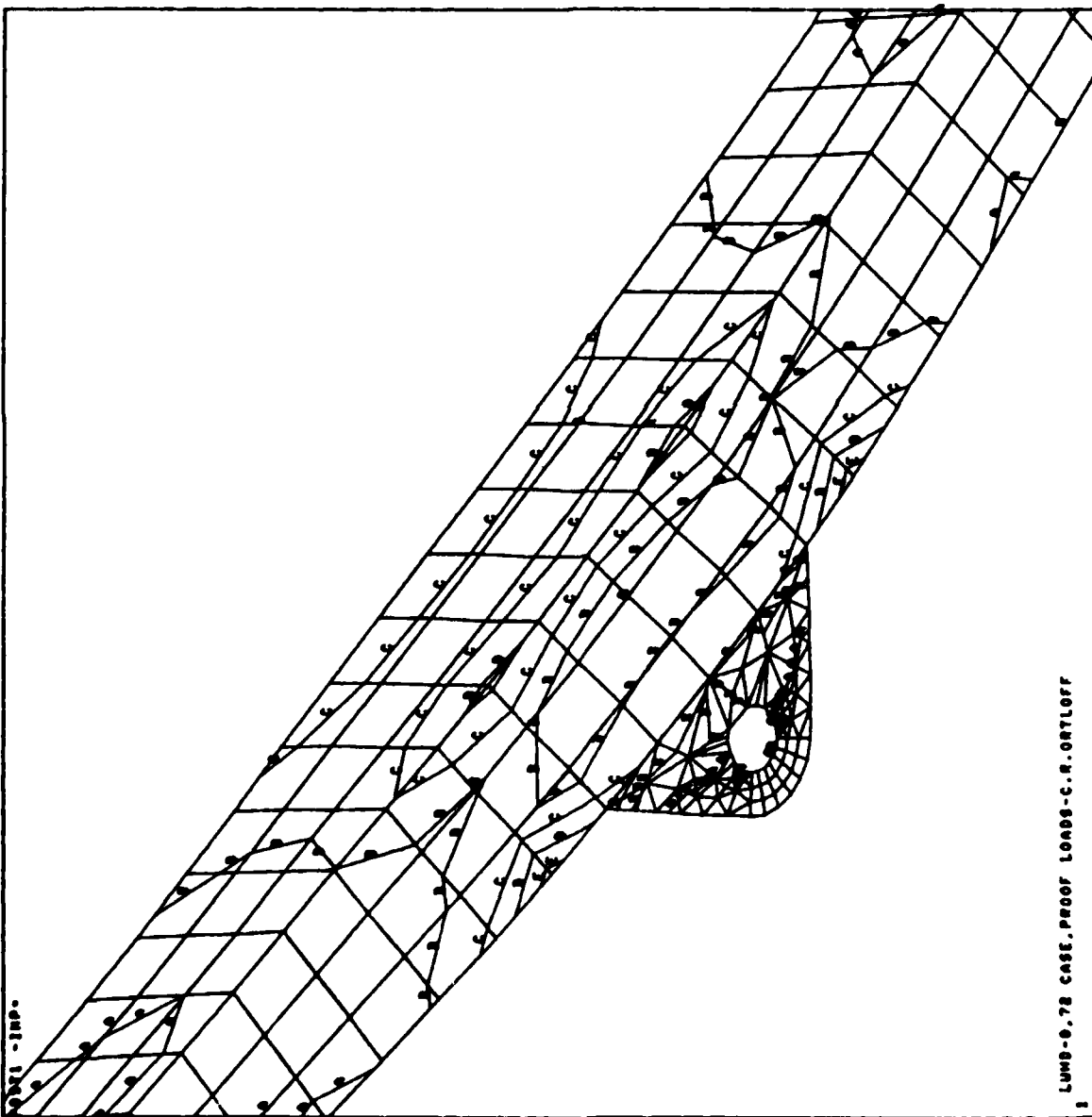
ANSYS 4.20
 DEC 26 1986
 14180150
 POST1 STRESS
 STEP=1
 FREQ=1
 TIME=.046
 SLOC
 TOP
 ZOOM
 MU=1
 VU=1
 VU=1
 20--1
 8 DISP=73.8
 8 XF=81.8
 8 VF=87.7
 8 ZF=4.17
 VARY=1.3
 HIDDEN
 RM=87005
 RM=880
 A=11896
 B=23114
 C=34332
 D=45550
 E=56768



ANSYS 4.20
 DEC 26 1986
 14112168
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.046
 SIZE
 TOP
 ZOOM
 KU=1
 VU=1
 ZU=1
 1 DIST=72.8
 2 MF=51.2
 3 VF=27.7
 4 2F=4.17
 5 VRT0=1.3
 WIDEN
 RH=67886
 RH=680
 A=11806
 B=23114
 C=34332
 D=45550
 E=56768



ANSYS 4.20
 DEC 26 1986
 13:58:14
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.048
 SLOC
 TOP
 ZOOM
 XU=-1
 VU=-1
 ZU=-1
 1 DIST=22.7
 2 XF=41.2
 3 VF=47.1
 4 ZF=12.6
 VRT0=1.3
 HIDDEN
 RK=63157
 RM=0
 A=11896
 B=23114
 C=34332
 D=46550
 E=56768

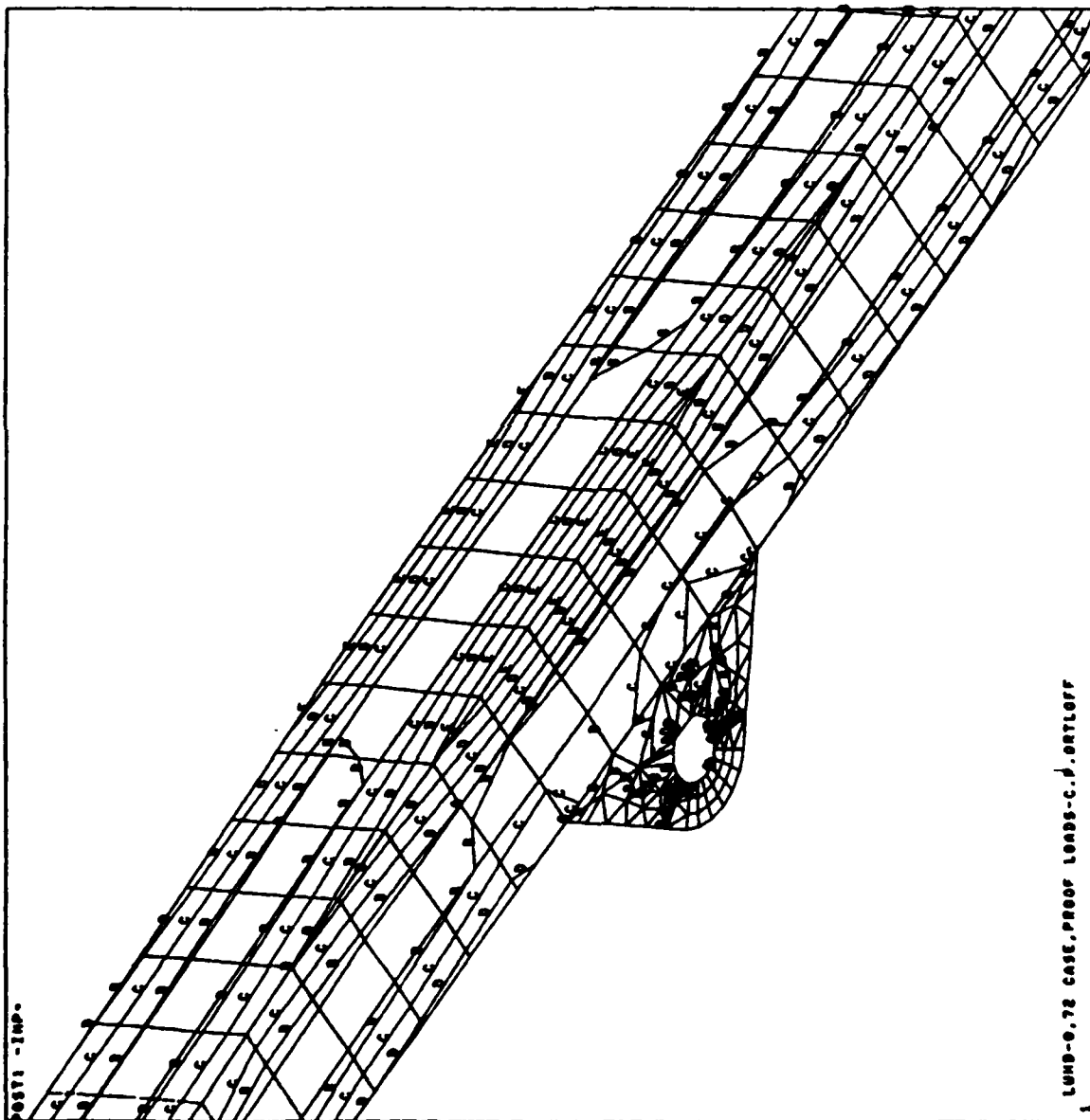


TIME: 0.00000-04 LAND CODE: 1

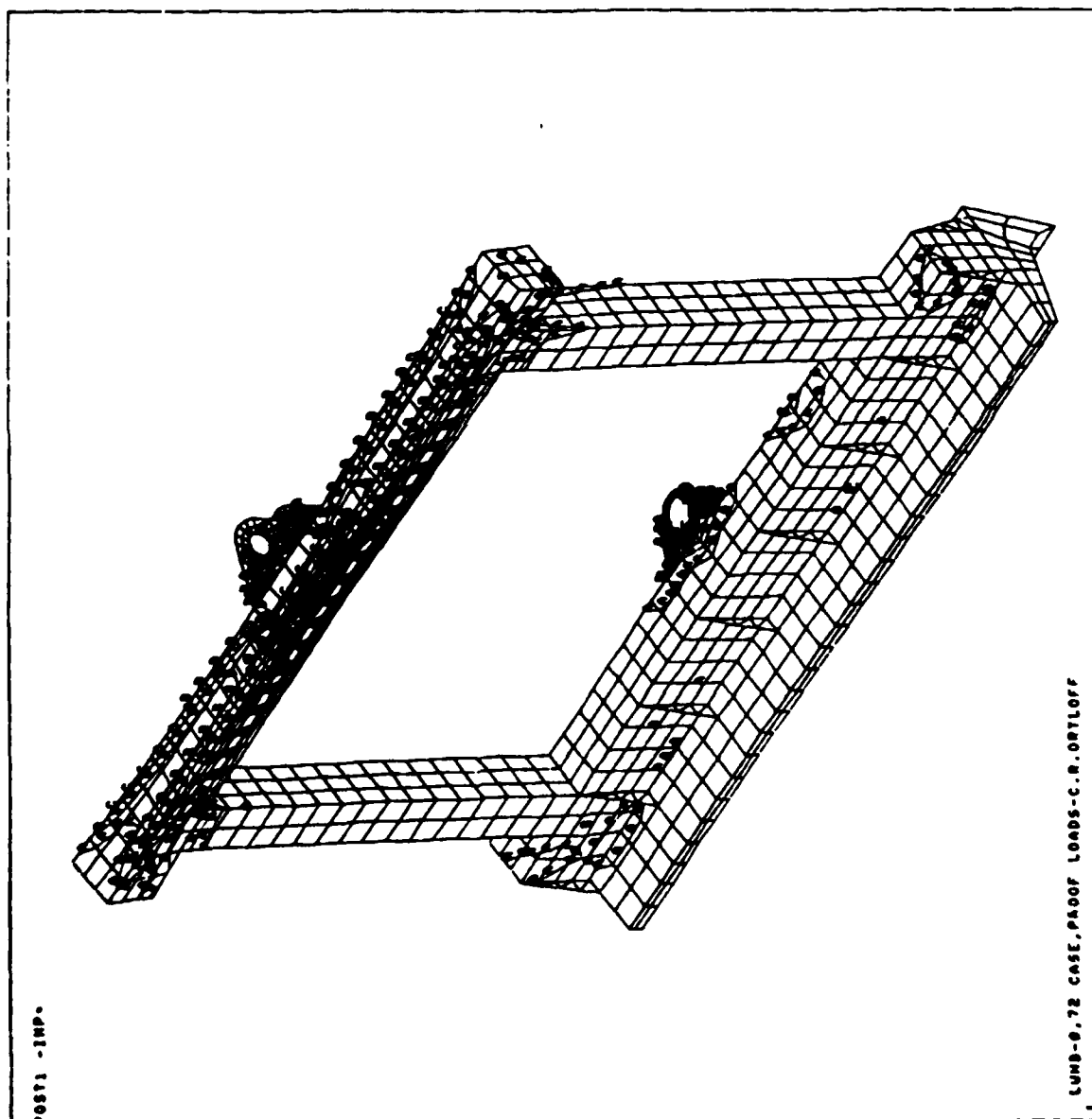
THE FOLLOWING N.V.2 FORMS ARE IN ORIGIN COUNTRIES

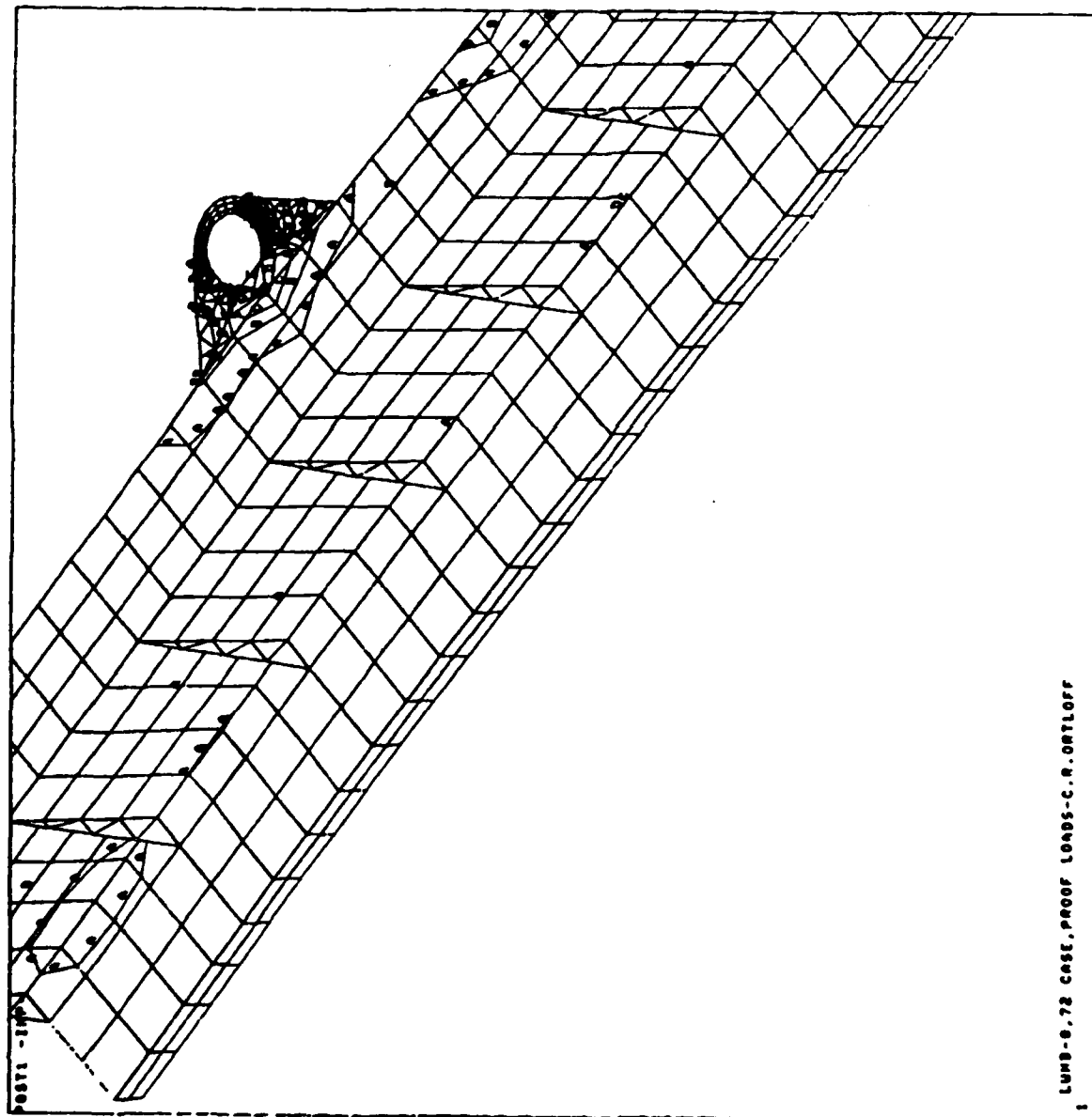
| NAME | PR | PR | PR | PR | PR |
|------|------|------|------|------|------|
| 1 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 2 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 3 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 4 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 5 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 6 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 7 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 8 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 9 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 10 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 11 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 12 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 13 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 14 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 15 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 16 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 17 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 18 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 19 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 20 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 21 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 22 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 23 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 24 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 25 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 26 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 27 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 28 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 29 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 30 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 31 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 32 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 33 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 34 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 35 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 36 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 37 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 38 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 39 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 40 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 41 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 42 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 43 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 44 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 45 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 46 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 47 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 48 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 49 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 50 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 51 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 52 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 53 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 54 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 55 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 56 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 57 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 58 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 59 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 60 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 61 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 62 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 63 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 64 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 65 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 66 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 67 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 68 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 69 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 70 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 71 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 72 | 1000 | 1000 | 1000 | | |

ANSYS 4.80
 DEC 20 1980
 13145310
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.280
 SICE
 TOP
 ZOOM
 RU=-1
 VU=-1
 ZU=1
 2 DIST=22
 2 XF=43.7
 2 YF=48.8
 2 ZF=16.8
 VRT0=1.81
 HIDDEN
 RM=18431
 RM=0
 A=3178
 B=6220
 C=9280
 D=12331
 E=15382



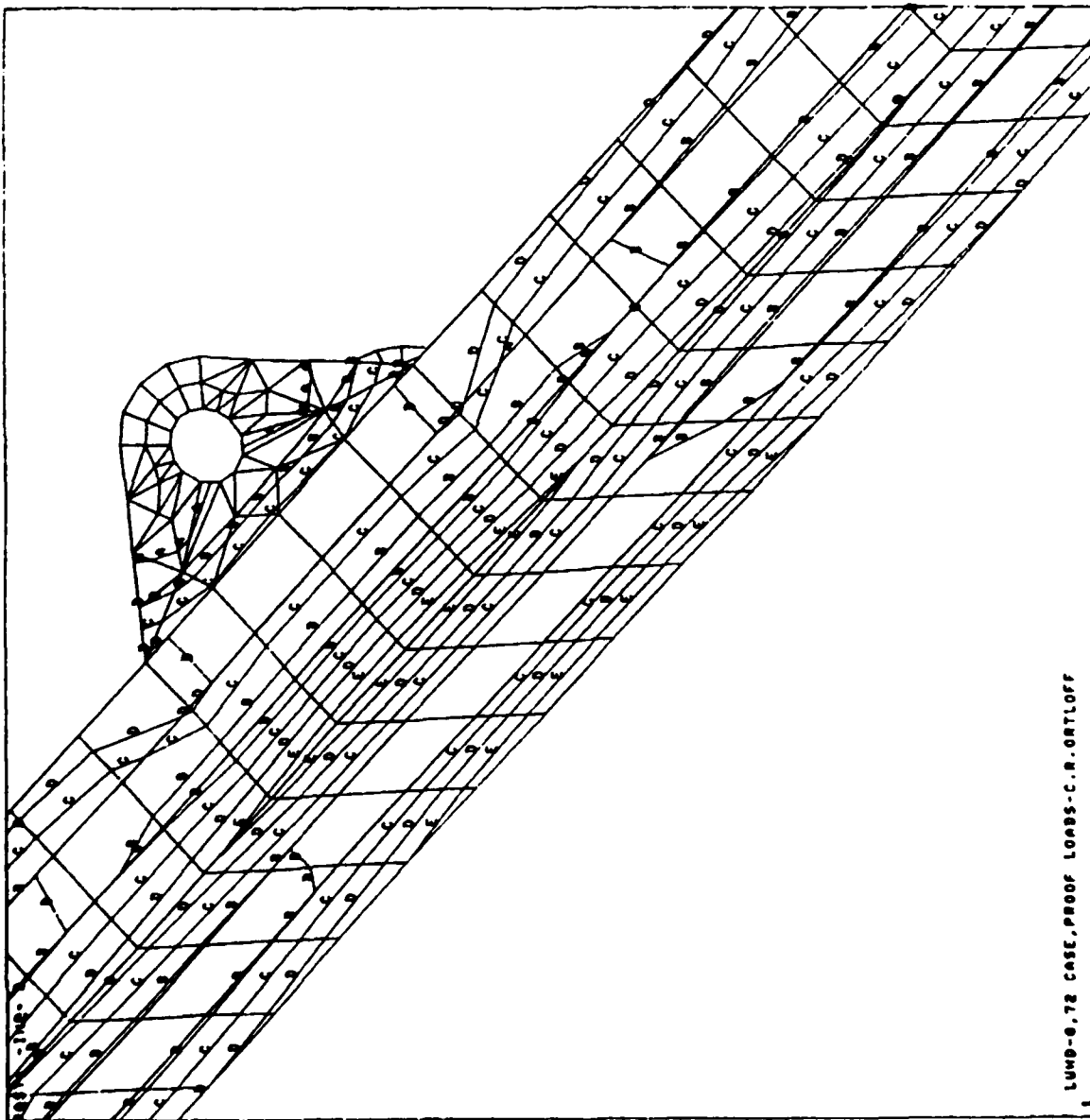
ANSYS 4.28
 DEC 28 1986
 13:58:58
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.258
 SICE
 TOP
 ZOOM
 RV=1
 VU=1
 ZU=1
 * DIST=68.7
 * XF=51.2
 * YF=27.7
 * ZF=4.17
 V870=1.21
 MIDEN
 MN=10431
 MN=128
 A=3178
 B=6229
 C=9280
 D=12321
 E=15382



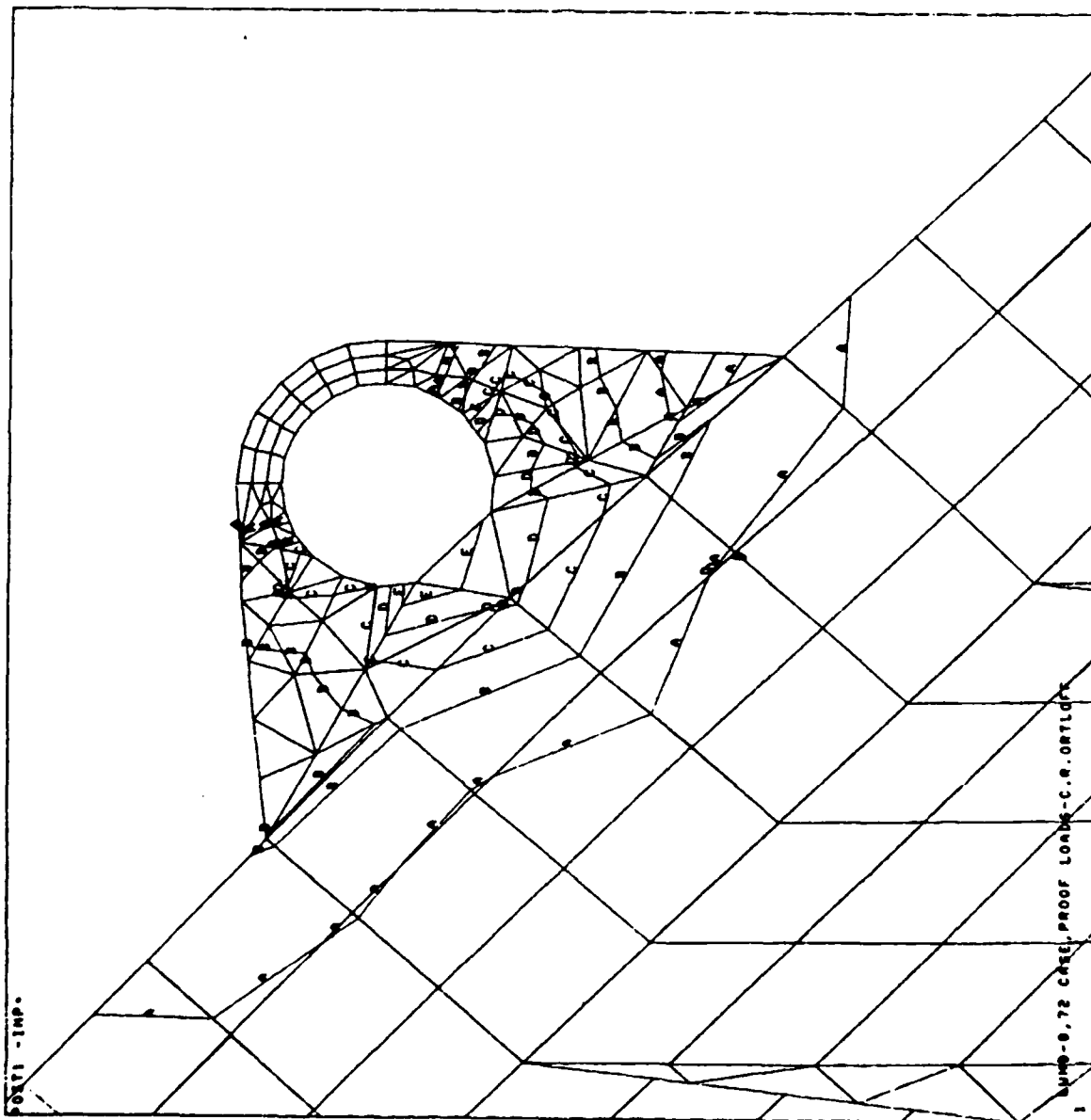


ANSYS 4.00
 DEC 28 1986
 13158150
 POST1 STRESS
 STCP=1
 ITER=1
 TIME=.358
 SICE
 TOP
 ZOOM
 XU=1
 VU=1
 ZU=1
 1 8187-33.3
 2 8 XF-53.6
 3 8 VF-5.13
 4 26-24.2
 5 VRTD-1.34
 MIDDEN
 RM-17588
 RM-6
 A-3178
 B-6229
 C-9280
 D-12331
 E-15382

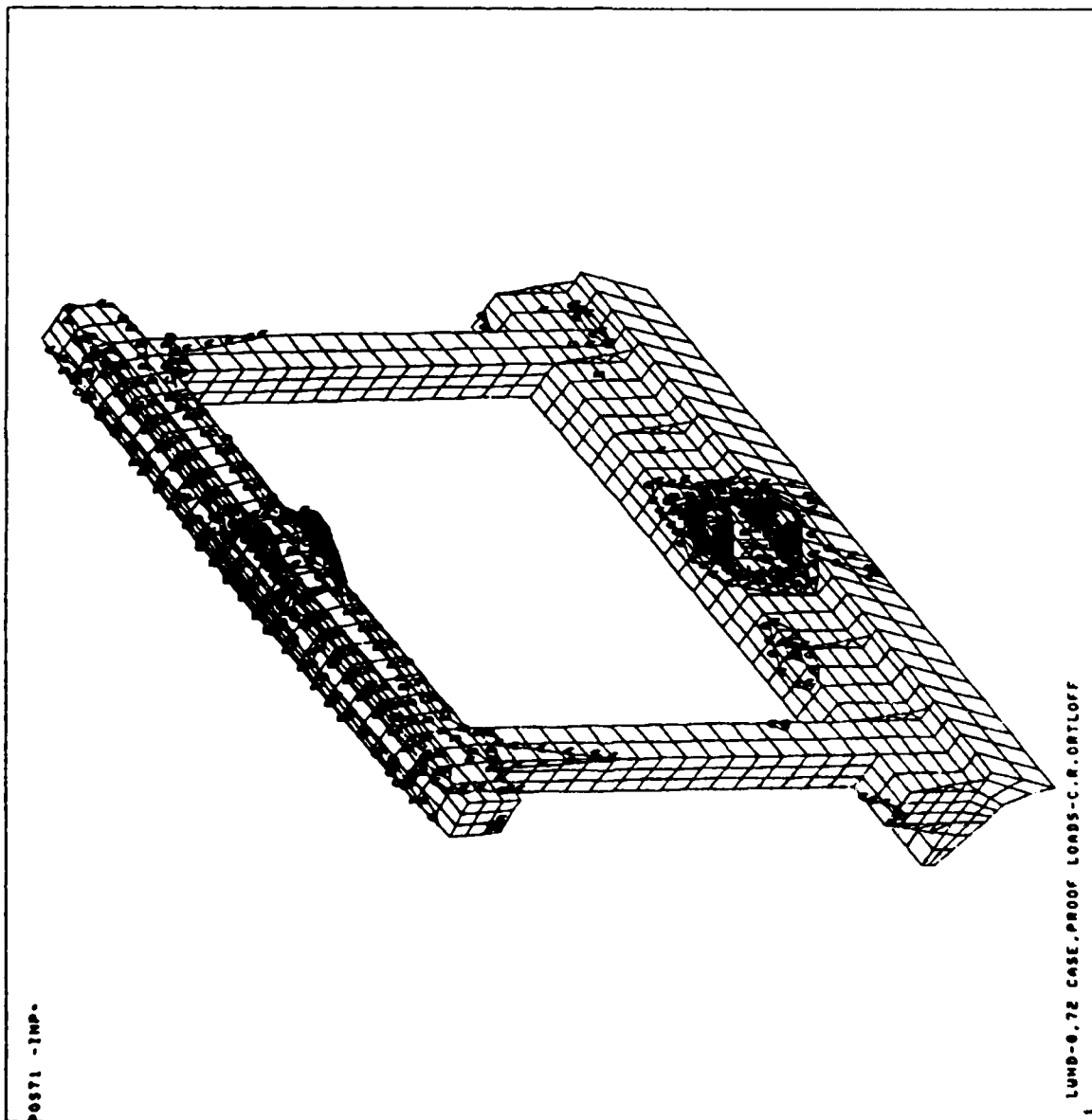
ANSYS 4.2B
 DEC 28 1986
 1410312
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.858
 SICE
 TOP
 200H
 XU=1
 YU=1
 ZU=1
 1 DIST=20.1
 2 XF=42.8
 3 YF=46.6
 4 ZF=6.39
 VRT0=1.81
 MIBDEM
 MX=18431
 MY=0
 A=3178
 B=6229
 C=9280
 D=12331
 E=15382



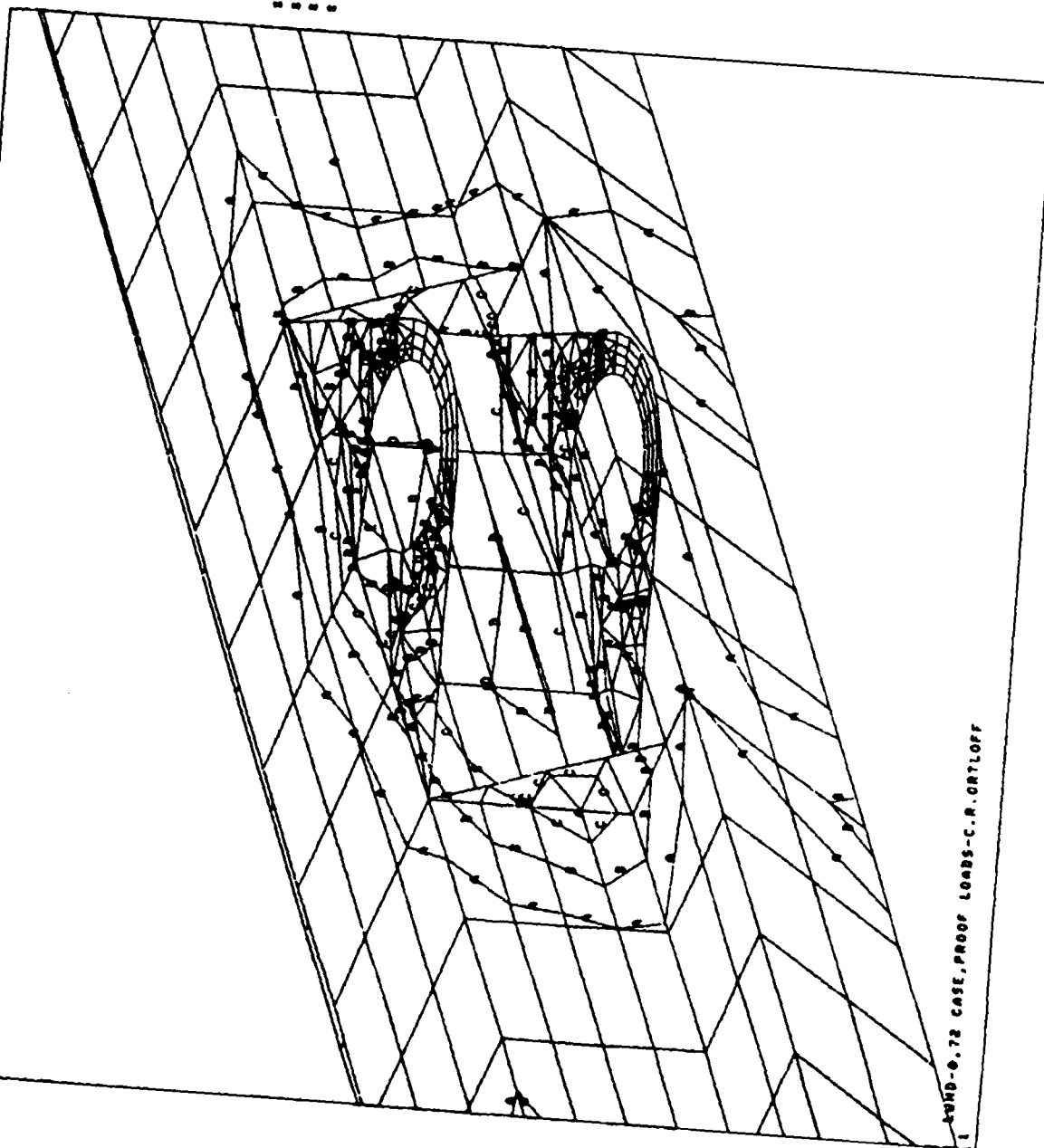
ANSYS 4.20
 DEC 20 1986
 14122117
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.250
 SICE
 TOP
 ZOOM
 KU=1
 VU=1
 ZU=1
 8 DIST=12.3
 8 XF=60.6
 8 YF=15.5
 8 ZF=6.94
 VRT0=1.84
 WIDEN
 RM=17599
 RM=6
 A=3178
 B=6220
 C=9280
 D=12331
 E=15382



ANSYS 4.28
 DEC 28 1986
 14149142
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.258
 SIZE
 TOP
 ZOOM
 KU=1
 VU=1
 ZU=-1
 DIST=232
 XC=54.2
 YF=26.4
 ZF=4.86
 XRT0=2.77
 YRT0=4
 HIDDEN
 RX=18431
 RM=129
 A=3178
 B=6229
 C=9280
 D=12331
 E=15382



POST1 -IMP.



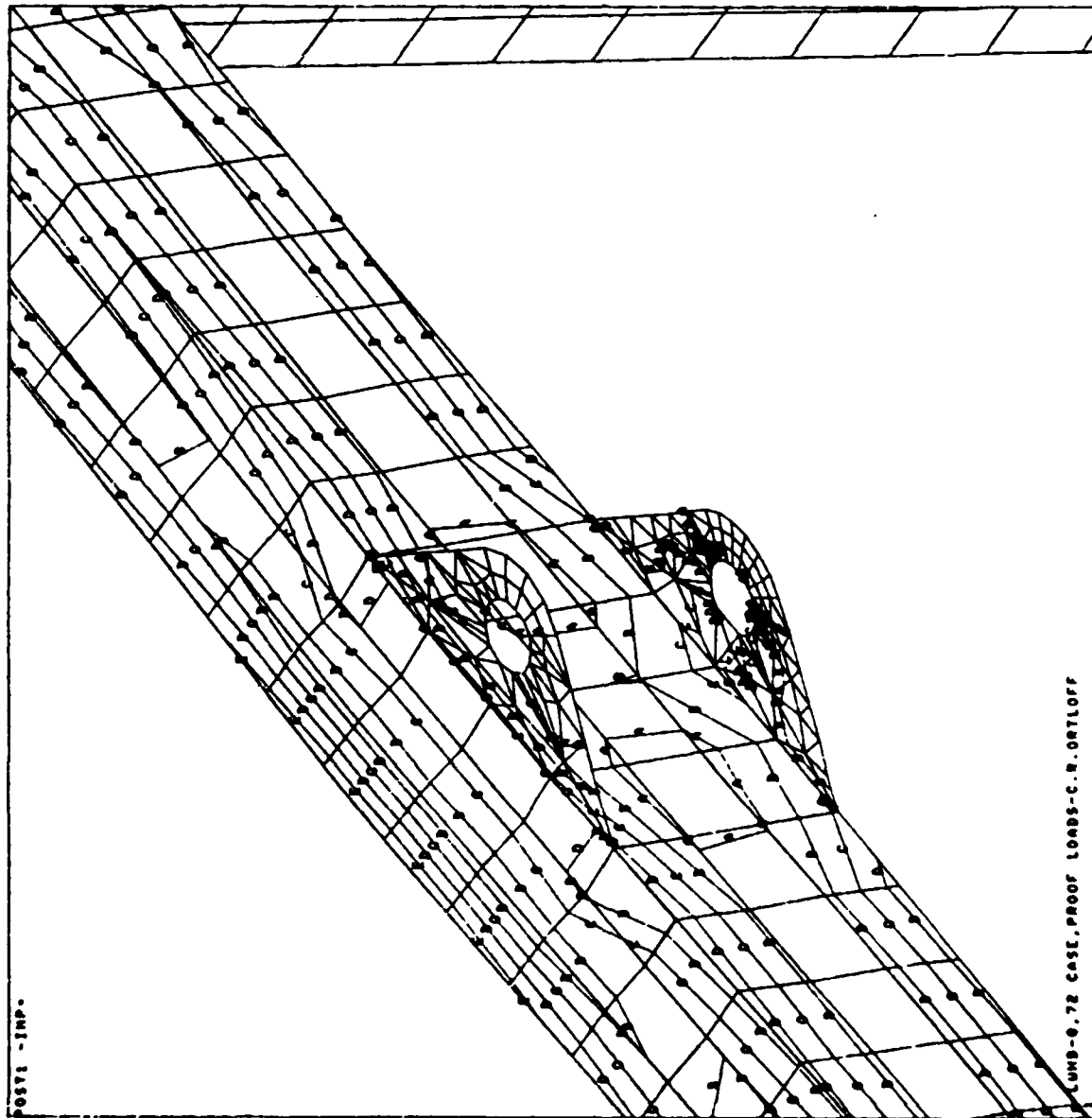
1 SUBD-0.72 CASE, PROOF LOADS-C.R. OUTFLOW

ANSYS 4.28
DEC 28 1986
1413113
POST1 STRESS
STEP=1
ITER=1
TIME=.000
SIZE
TOP
ZOOM
NU=1
VU=1
ZU=1
1 DIST=34.2
2 XF=59.7
3 YF=9.58
4 ZF=-6.37
KATO=2.77
VATO=1.84
HIDDEN
RX=17588
RY=0
A=3178
B=6229
C=9280
D=12331
E=15382

BOTTOM

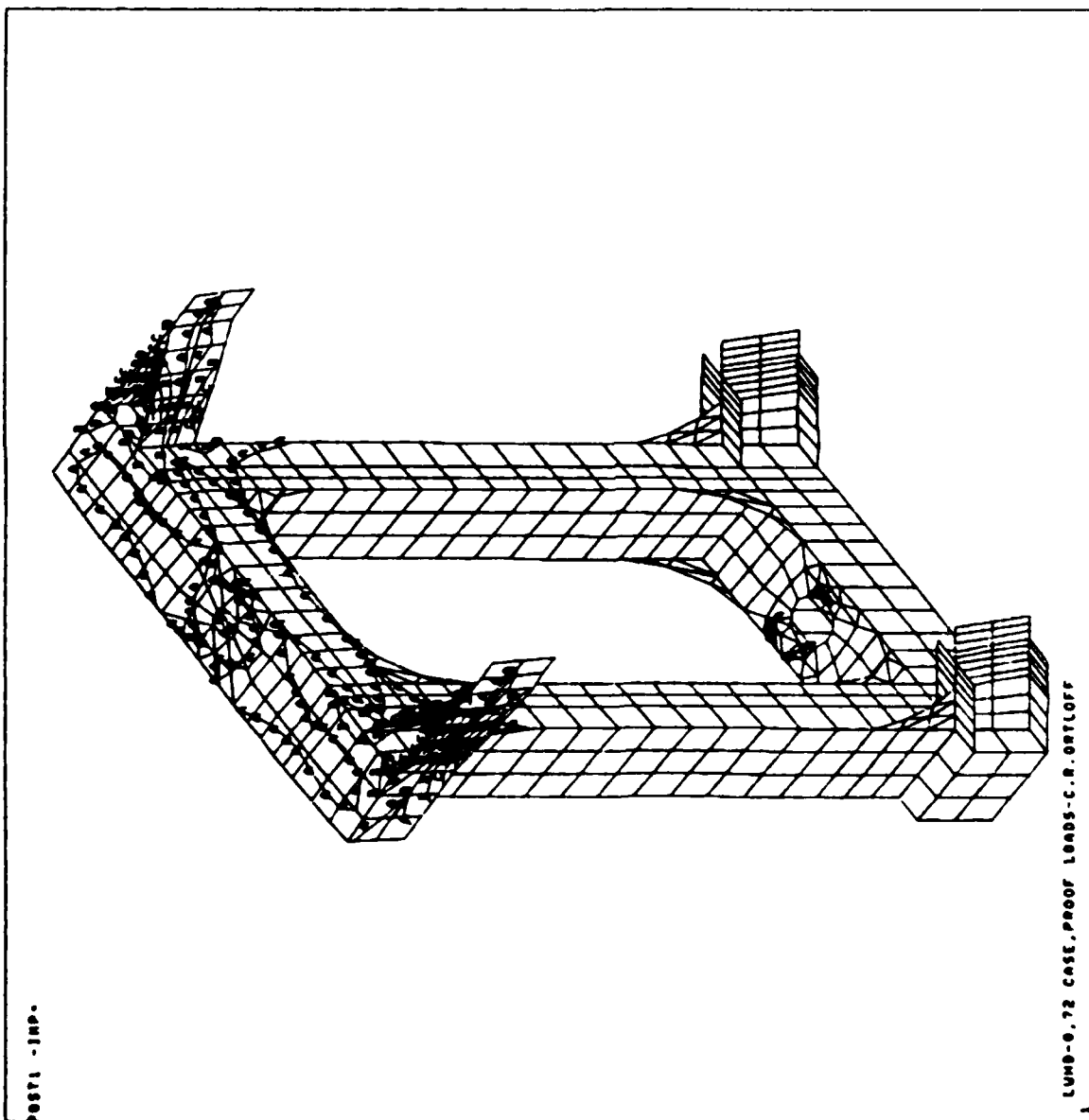
7.5

ANSYS 4.20
 DEC 28 1986
 14:41:07
 POST1 STRESS
 STEP=1
 LAYER=1
 TIME=.250
 SICE
 TOP
 ZOOM
 XU=1
 VU=1
 ZU=-1
 1 BIST-56.4
 2 XF-37.9
 3 VF-49.8
 4 ZF-11.9
 5 XRT0-2.77
 6 VRT0-4
 7 MIBEN
 8 MX-18431
 9 RM-9
 10 A-3178
 11 B-6229
 12 C-9280
 13 D-12331
 14 E-15382

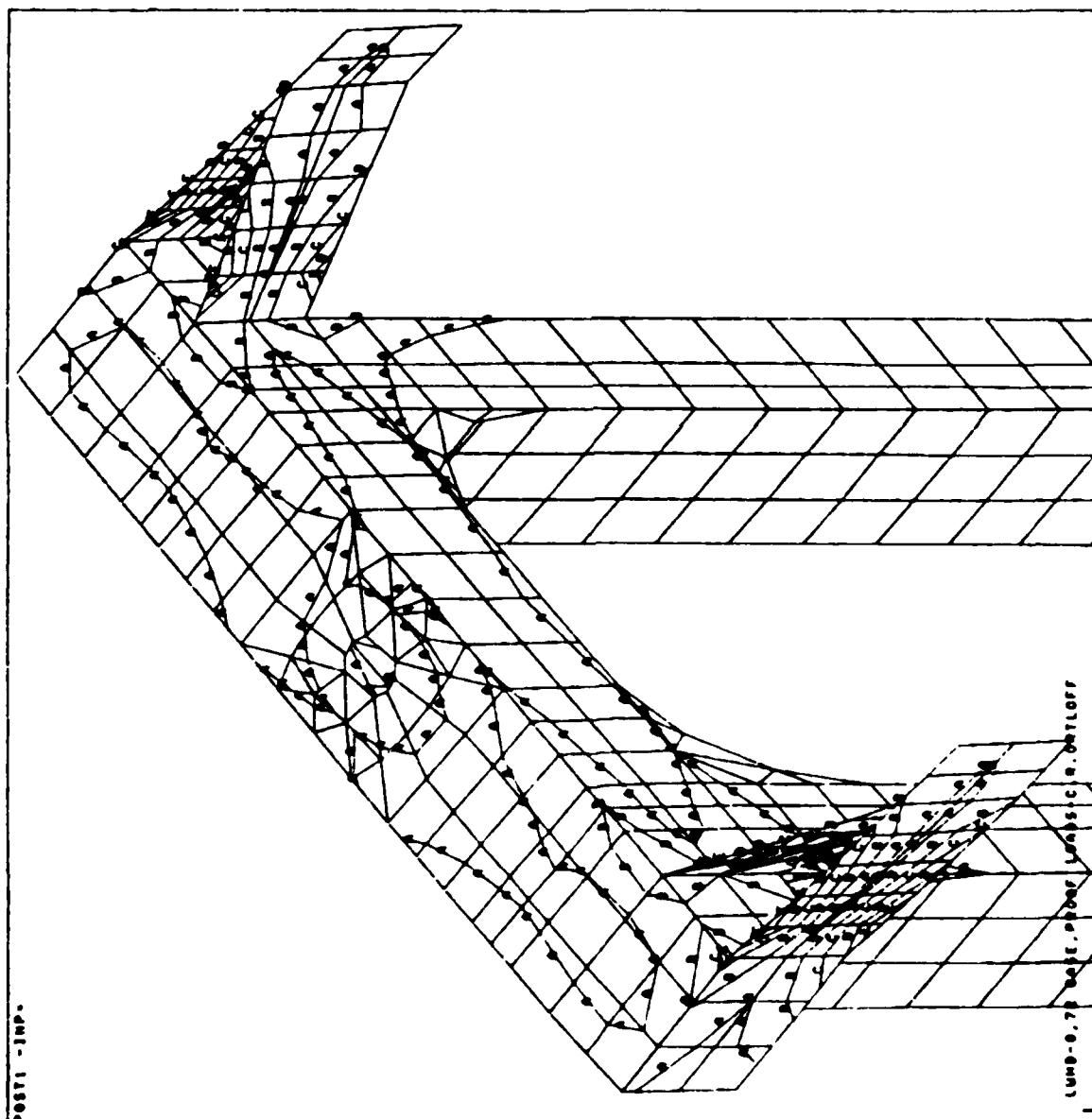


TOP

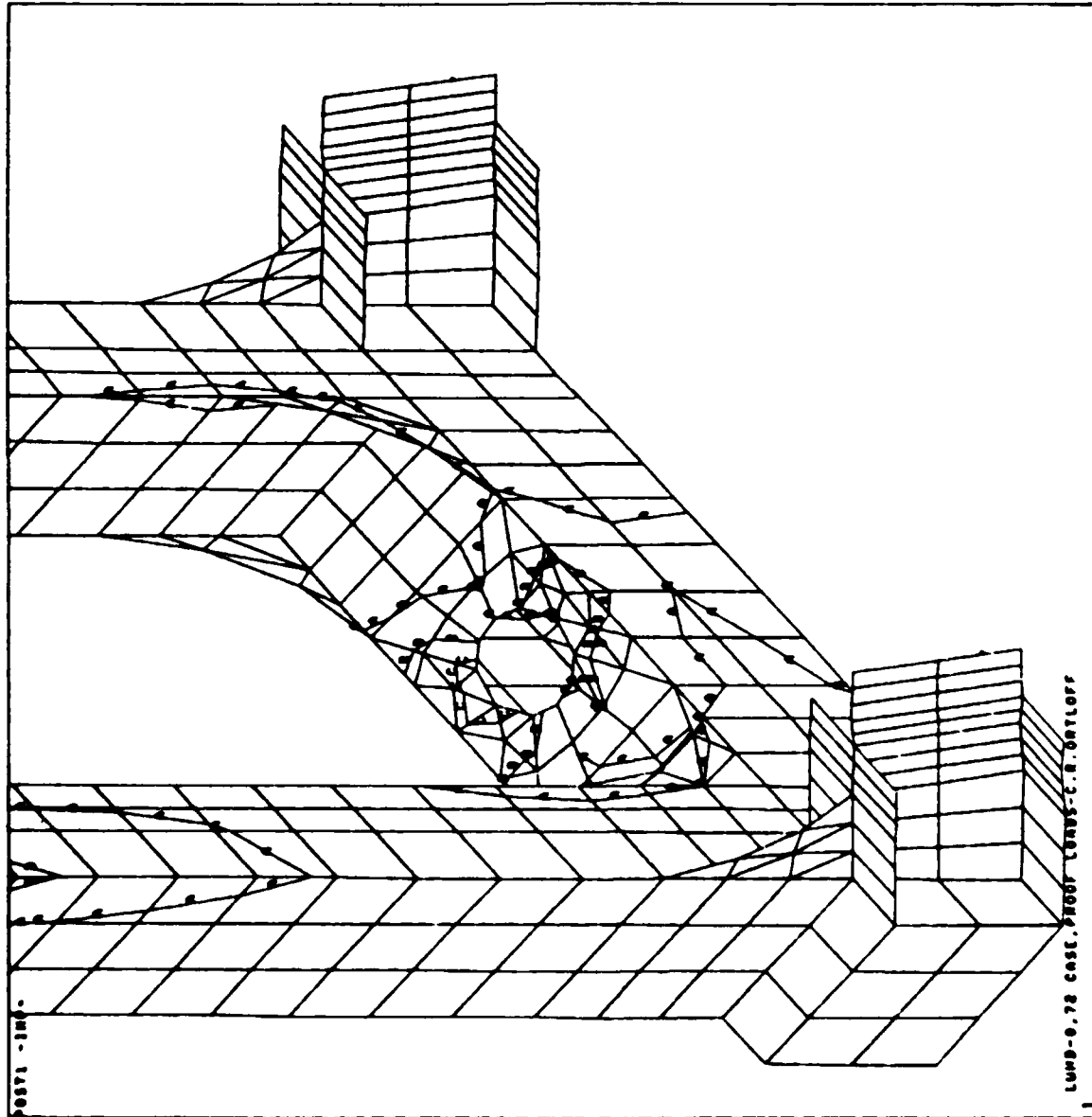
ANSYS 4.20
 DEC 28 1986
 14157126
 POST1 STRESS
 STEP=1
 LAYER=1
 TIME=.258
 SIZE
 TOP
 ZOOM
 XU=1
 YU=1
 ZU=-1
 DIST=131
 XF=51.6
 YF=35.8
 ZF=-8.57
 XRT0=2.77
 YRT0=4
 HIDDEN
 NX=192030
 NN=127
 A=32111
 B=64087
 C=96083
 D=128069
 E=160065



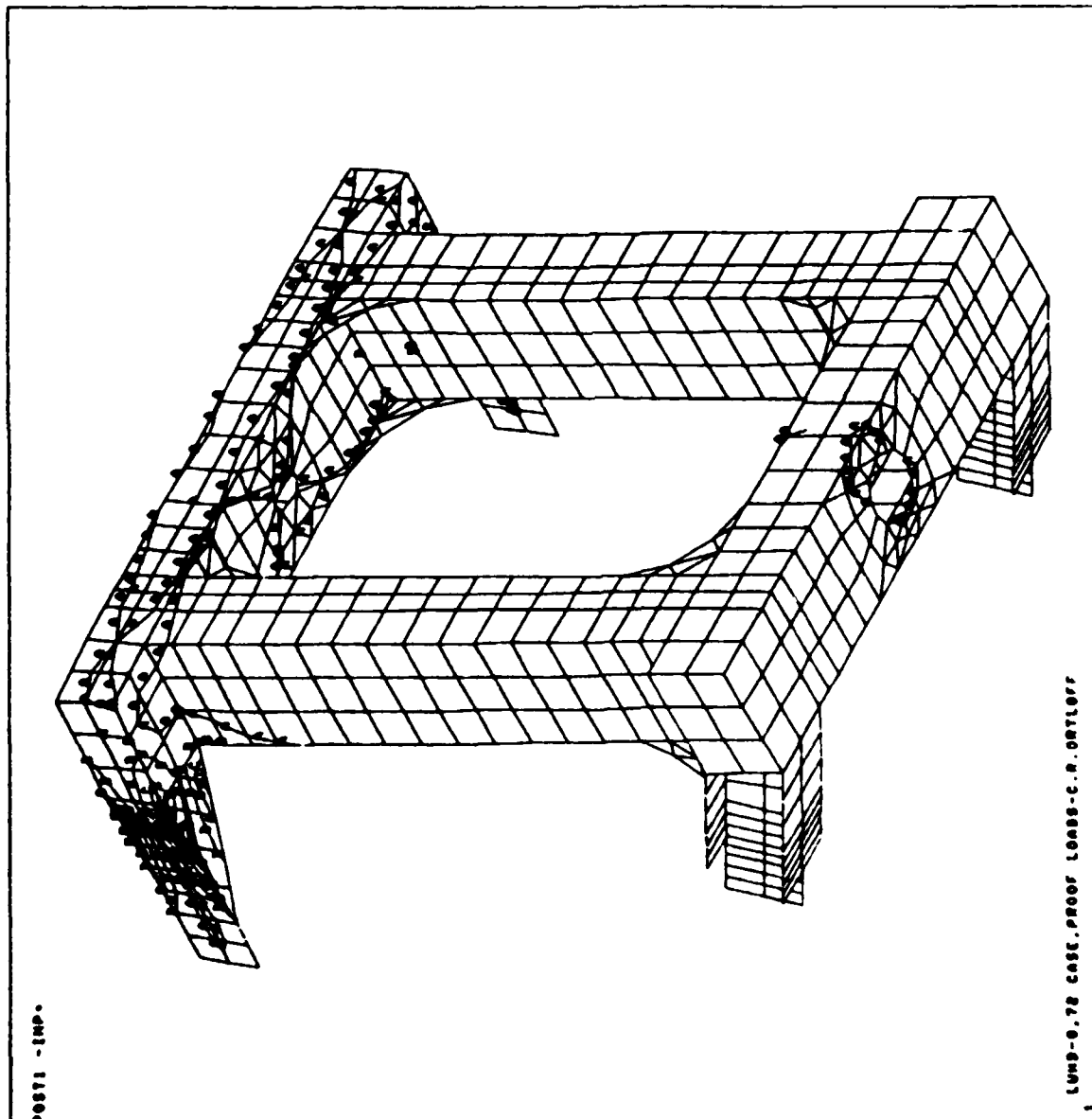
ANSYS 4.20
 DEC 28 1986
 14157136
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.258
 SIGC
 TOP
 ZOOM
 KU=1
 VU=1
 ZU=1
 1 BIST-66.9
 2 XF-46.8
 3 VF-46.8
 4 ZF-2.64
 KRYO-2.77
 VRYO-4.13
 MIDDEN
 AK=192030
 RM=0
 A=32111
 B=64007
 C=96003
 D=128009
 E=160055



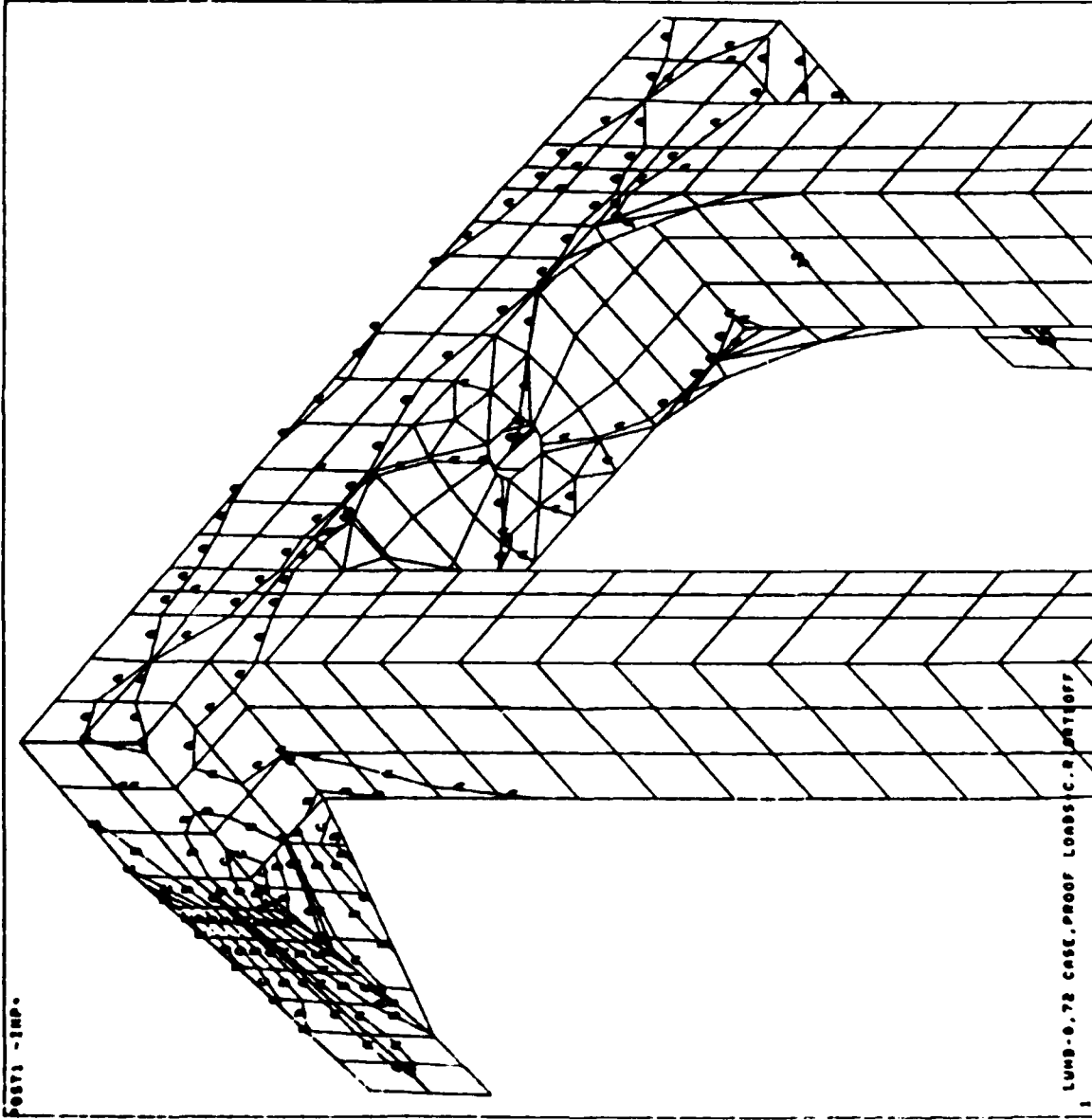
ANSYS 4.20
 DEC 20 1988
 15:03:59
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.298
 SISE
 TOP
 ZOOM
 KU=1
 VU=1
 ZU=-1
 * BIST-64.5
 * KF=58.5
 * VF=22.1
 * ZF=-14.8
 * KATO=2.77
 * VETO=4.47
 * HIDDEN
 * K=52420
 * M=0
 * A=13118
 * B=24113
 * C=36108
 * D=48102



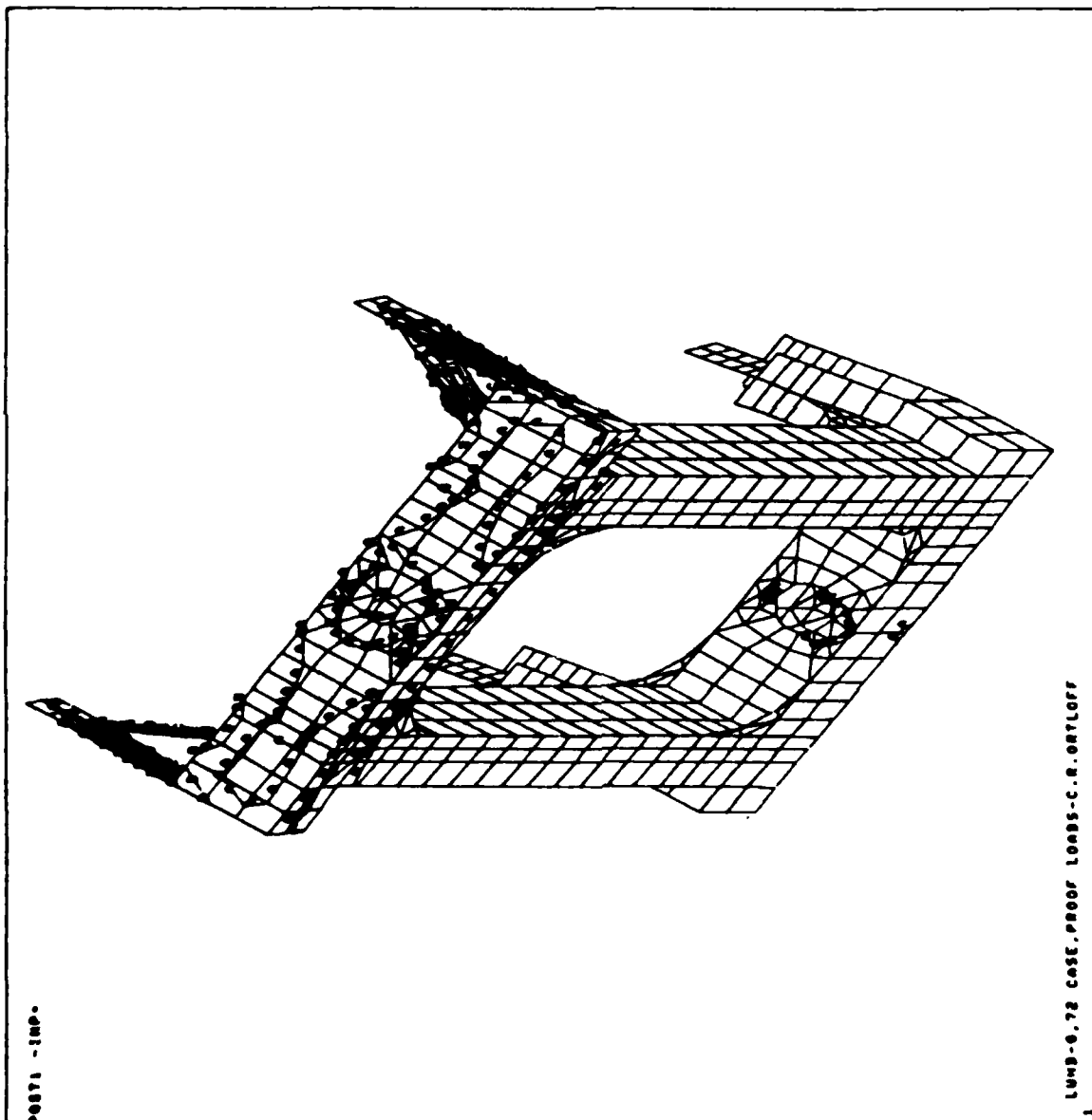
ANSYS 4.20
 DEC 20 1986
 15:10:25
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.250
 SLOC
 TOP
 NU=1
 VU=1
 20=1
 S1S7=32.7
 SF=51.6
 VF=35.8
 ZF=-8.57
 MIDEN
 ME=102030
 MN=127
 A=32111
 B=64097
 C=06083
 D=128069
 E=160055

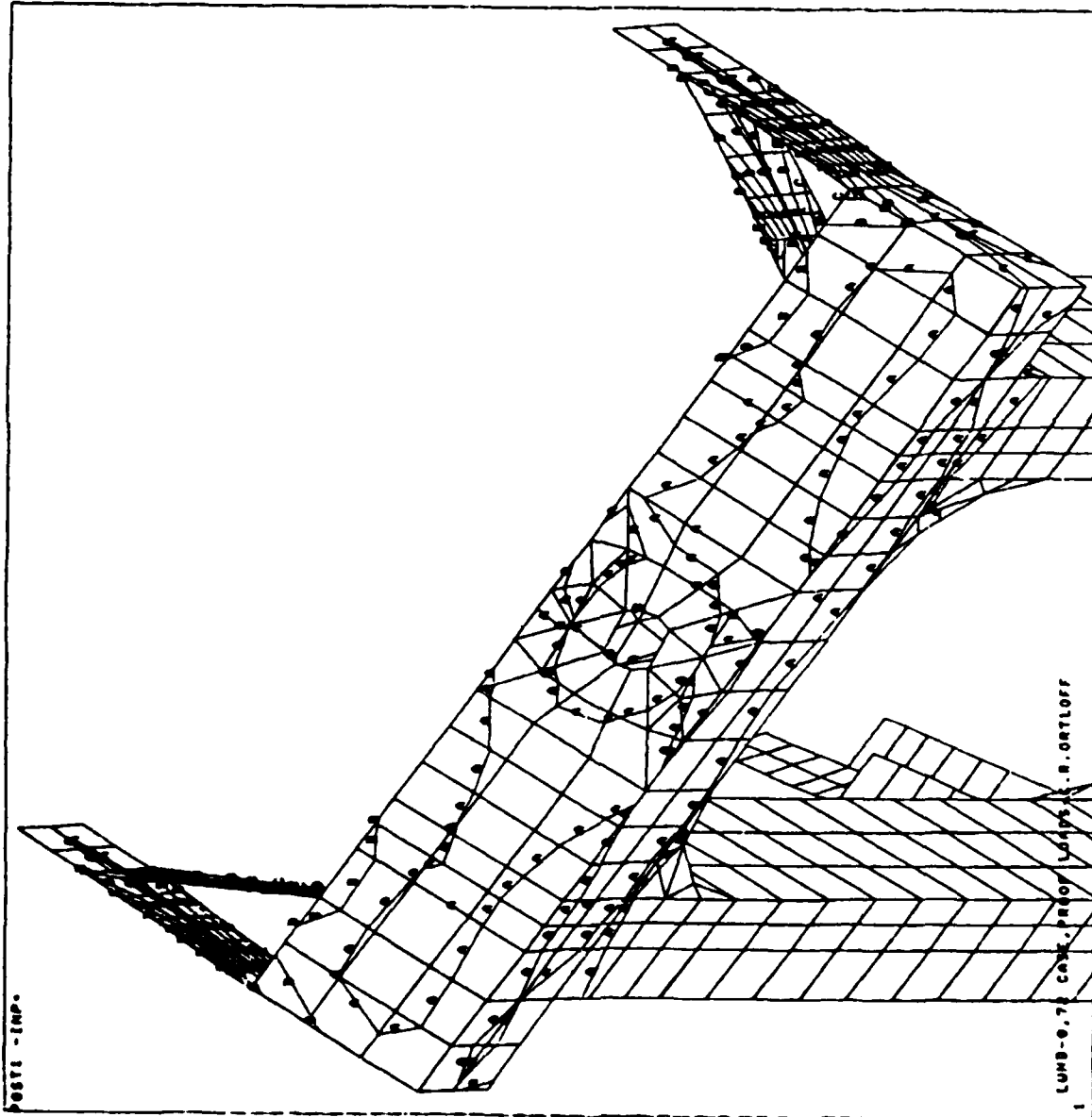


ANSYS 4.20
 DEC 20 1986
 15:10:25
 POST1, STRESS
 STEP=1
 ITER=1
 TIME=.250
 SLOC
 TOP
 2004
 NU=-1
 VU=-1
 20=1
 3157=24
 37=45.4
 37=47.4
 37=-2.6
 VARY=1.55
 U100EN
 RX=102030
 RN=0
 A=32111
 B=64097
 C=80083
 D=120060
 E=160055



ANSYS 4.20
 DEC 20 1986
 15:17:17
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.888
 SICE
 TOP
 ZOOM
 RV=.4
 VU=1
 ZU=.6
 D187=50.8
 XF=54.2
 VF=35.1
 ZF=9.2
 VRT0=1.56
 M188EN
 M2=192039
 MH=127
 A=32111
 B=64007
 C=86003
 D=128069
 E=160055



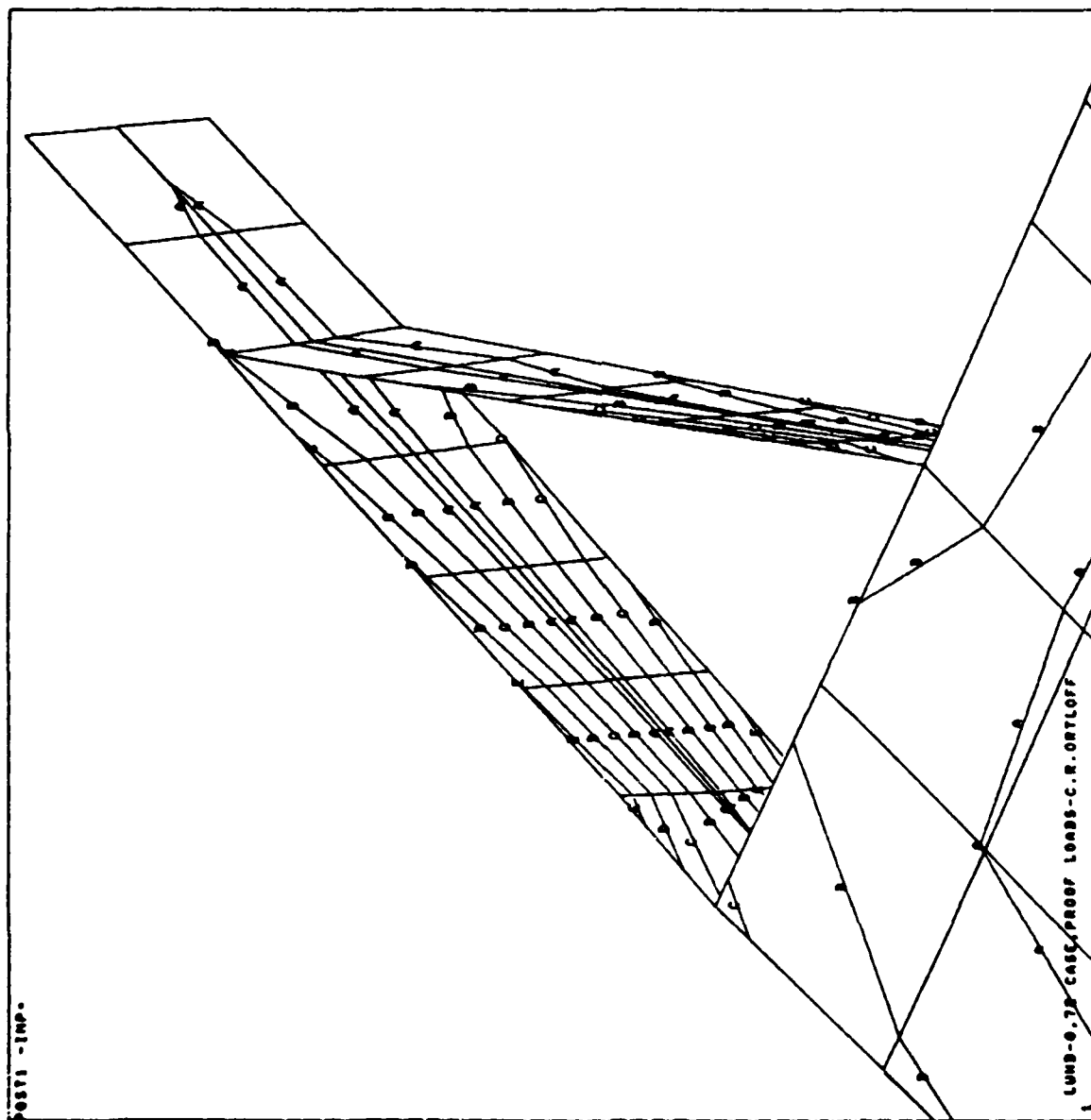


POST1 -IMP.

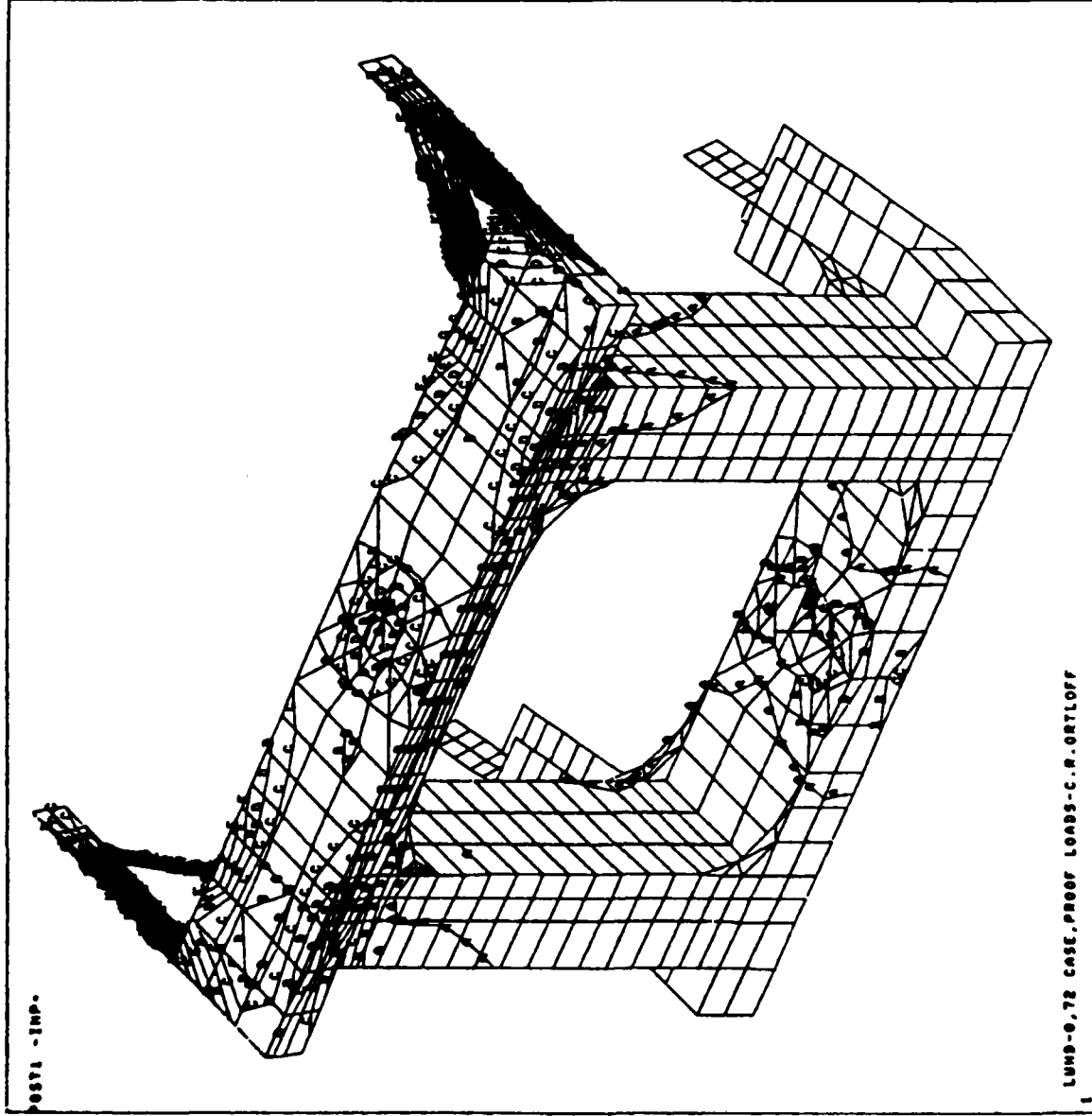
LUMB-9.75 CASE. PROOF LOADS L.R.ORTLOFF

ANSYS 4.28
DEC 28 1986
15:17:17
POST1 STRESS
STEP=1
ITER=1
TIME=.888
SIZE
TOP
ZOOM
XU=.4
VU=1
ZU=.6
2 DIST=28.5
3 XF=48.3
3 VF=42.6
3 ZF=16.7
KATO=1.13
KATO=1.56
MIDEN
MIDEN
MIDEN
A=22131
B=64987
C=86023
D=128069
E=160055

ANSYS 4.20
 DEC 28 1986
 15127140
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.050
 SIZE
 TOP
 ZOOM
 XU=.4
 YU=.1
 ZU=.6
 1 DIST=9.75
 2 XF=29.4
 3 YF=49.5
 4 ZF=15.6
 5 XRT0=1.87
 6 YRT0=1.56
 7 HIDDEN
 8 RH=105315
 9 RH=0
 10 A=32111
 11 B=64007
 12 C=96003
 13 D=128009
 14 E=160005



ANSYS 4.23
 DEC 28 1986
 15120111
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.250
 SICE
 TOP
 ZOOM
 XU=.4
 YU=1
 ZU=.6
 DIST=50.8
 XP=54.2
 YP=36.1
 ZP=-8.8
 XRTD=1.87
 YRTD=1.56
 WIDEN
 RX=192030
 RM=127
 A=12118
 B=24113
 C=36108
 D=48103
 E=60098
 F=72093
 G=84088
 H=96083
 I=108078
 J=120073
 K=132068
 L=144063
 M=156058
 N=168053
 O=180048



POST1 -IMP.

PLABEL,1,1

CONTOUR LABELING ON FOR WINDOW 1
NUMBER OF CONTOURS SET TO 10. USE /CONTOUR TO
SET DIFFERENT NUMBER OF CONTOURS (MAX. OF 24)

POST1 -IMP.

/CONTOUR,1,6

WINDOW 1 HAS 6 AUTOMATIC CONTOURS

POST1 -IMP.

PLNSTR,SIZE

PRODUCE STRESS PLOT, LABEL= SIZE AT TOP

ANSYS 4.20

DEC 28 1986

15:29:11

POST1 STRESS

STEP=1

ITER=1

TIME=.258

SIGE

TOP

ZOOM

KU=.4

VU=1

ZU=.6

8 DIST=13.6

8 XF=67.3

8 YF=37

8 ZF=-20.1

KRTO=1.88

VRTO=1.56

MIDRCH

MX=192039

MY=0

A=12118

B=24113

C=36108

D=48103

E=60098

F=72093

G=84088

H=96083

I=108078

J=120073

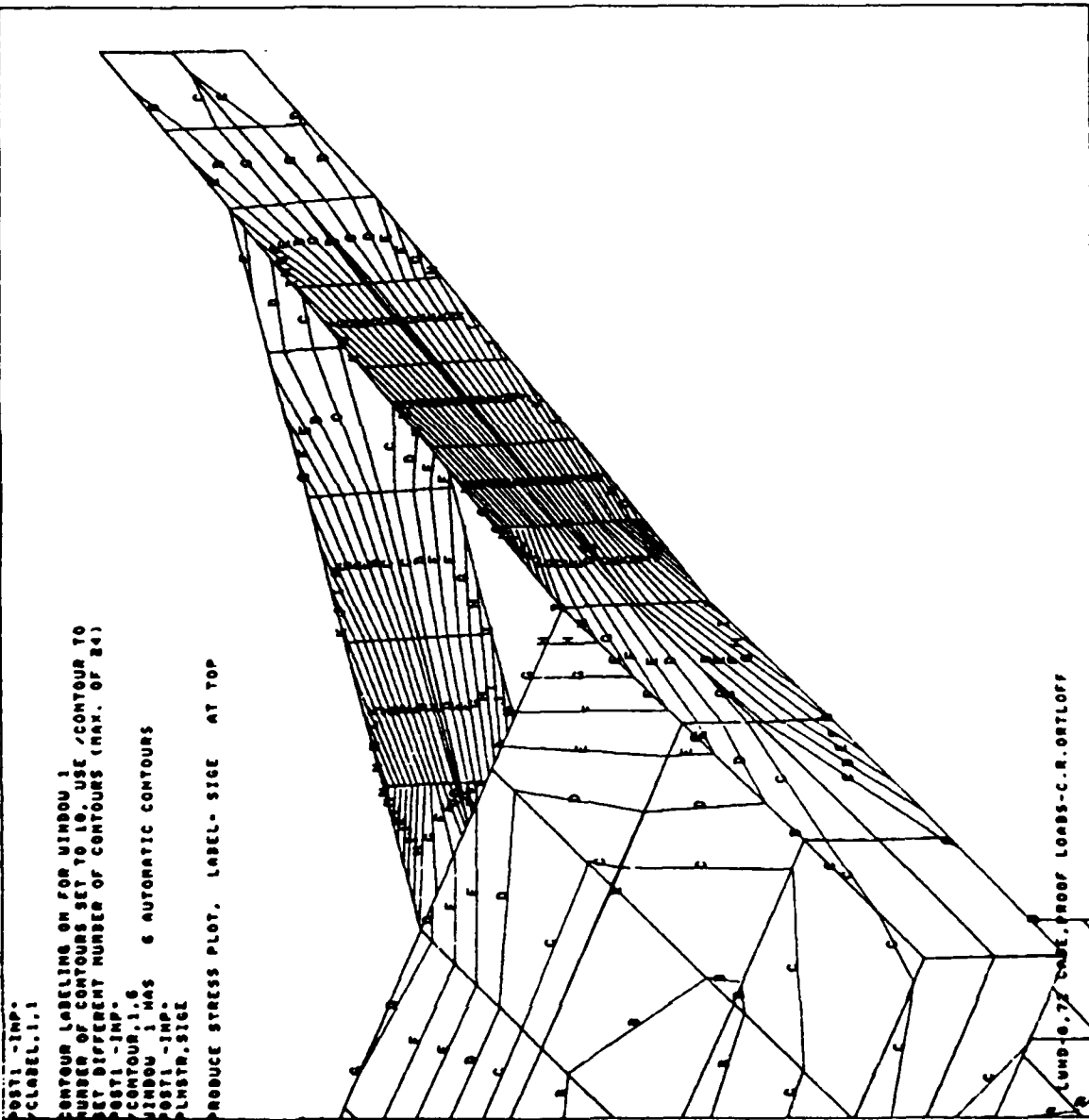
K=132068

L=144063

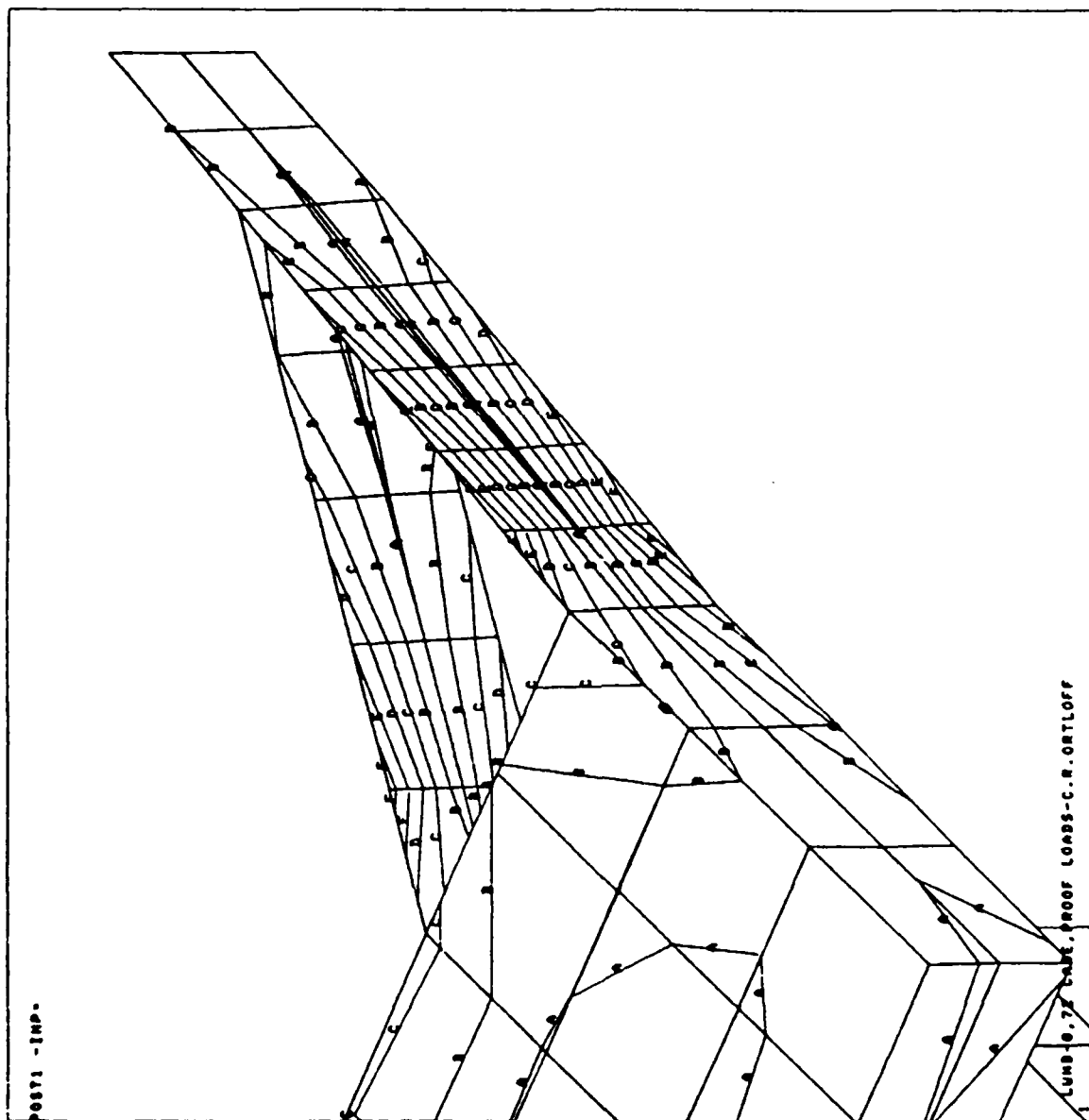
M=156058

N=168053

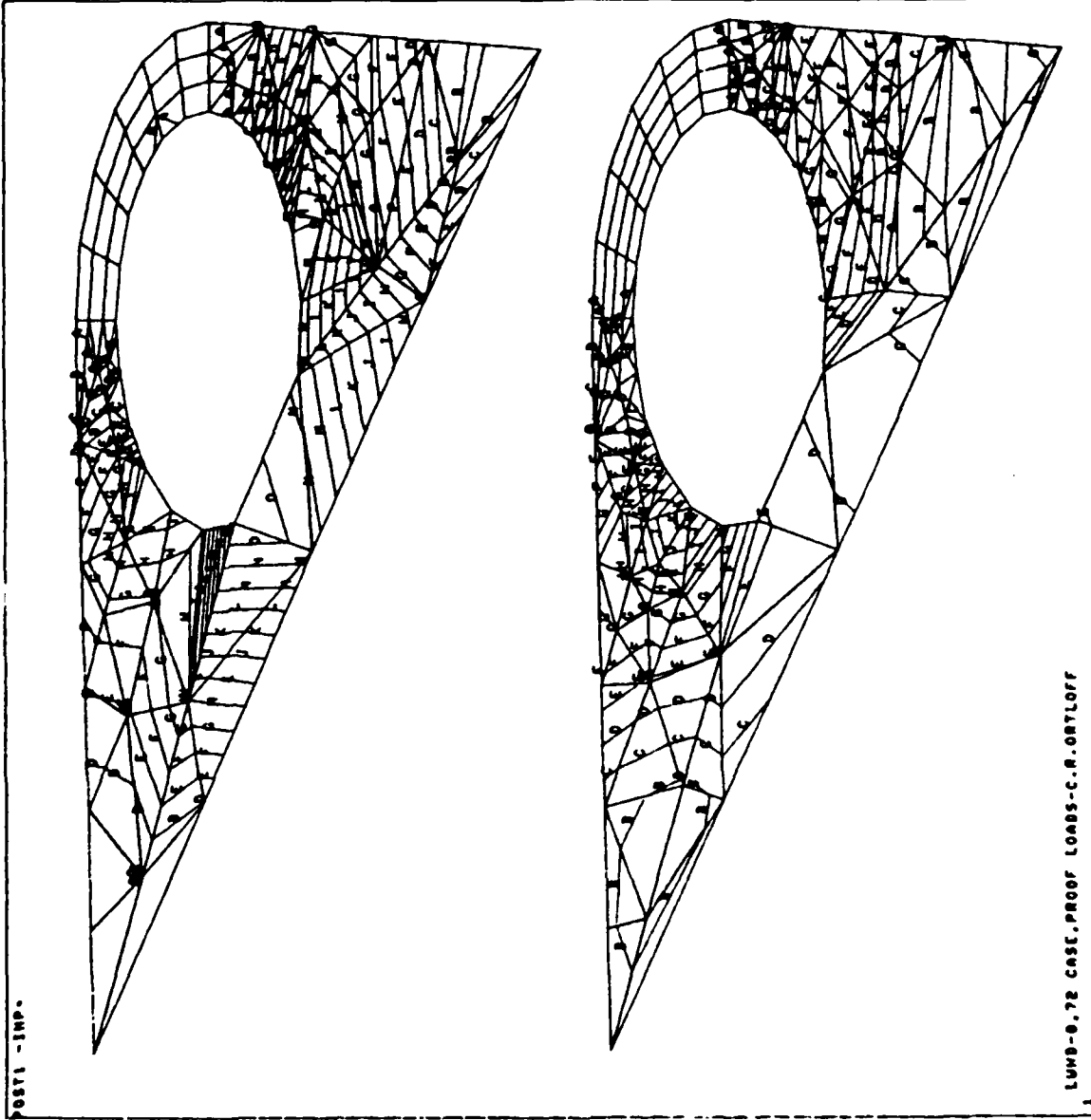
O=180048



ANSYS 4.28
 DEC 28 1986
 15132150
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.258
 SICE
 TOP
 ZOOM
 XU=.4
 VU=1
 ZU=.6
 2 DIST=13.5
 2 XF=67.3
 2 VF=37
 2 ZF=29.1
 XRT0=1.88
 YRT0=1.56
 HIDDEN
 RX=192039
 RM=0
 A=27541
 B=54958
 C=82376
 D=169792
 E=137209
 F=164626

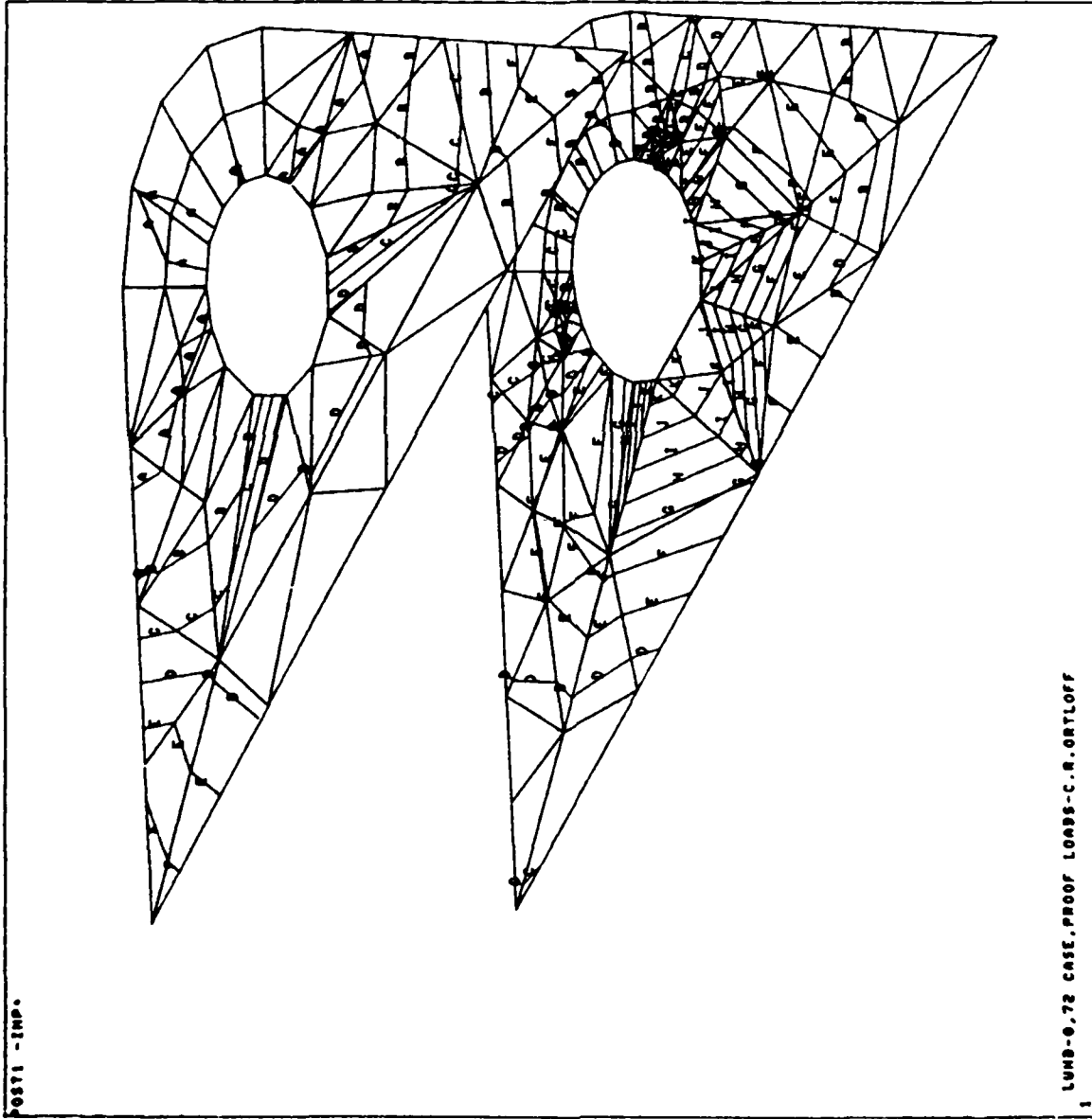


ANSYS 4.20
 DEC 20 1986
 15:34:25
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.288
 SICE
 TOP
 ZOOM
 X0=1
 Y0=1
 Z0=1
 DIST=11.7
 X1=61.8
 Y1=13.6
 Z1=8.93
 X2=0.196
 Y2=0.156
 HIDDEN
 MM=17599
 MM=120
 A=1220
 B=2312
 C=2494
 D=4496
 E=5588
 F=6680
 G=7772
 H=8864
 I=9956
 J=11048
 K=12140
 L=13232
 M=14324
 N=15416
 O=16508



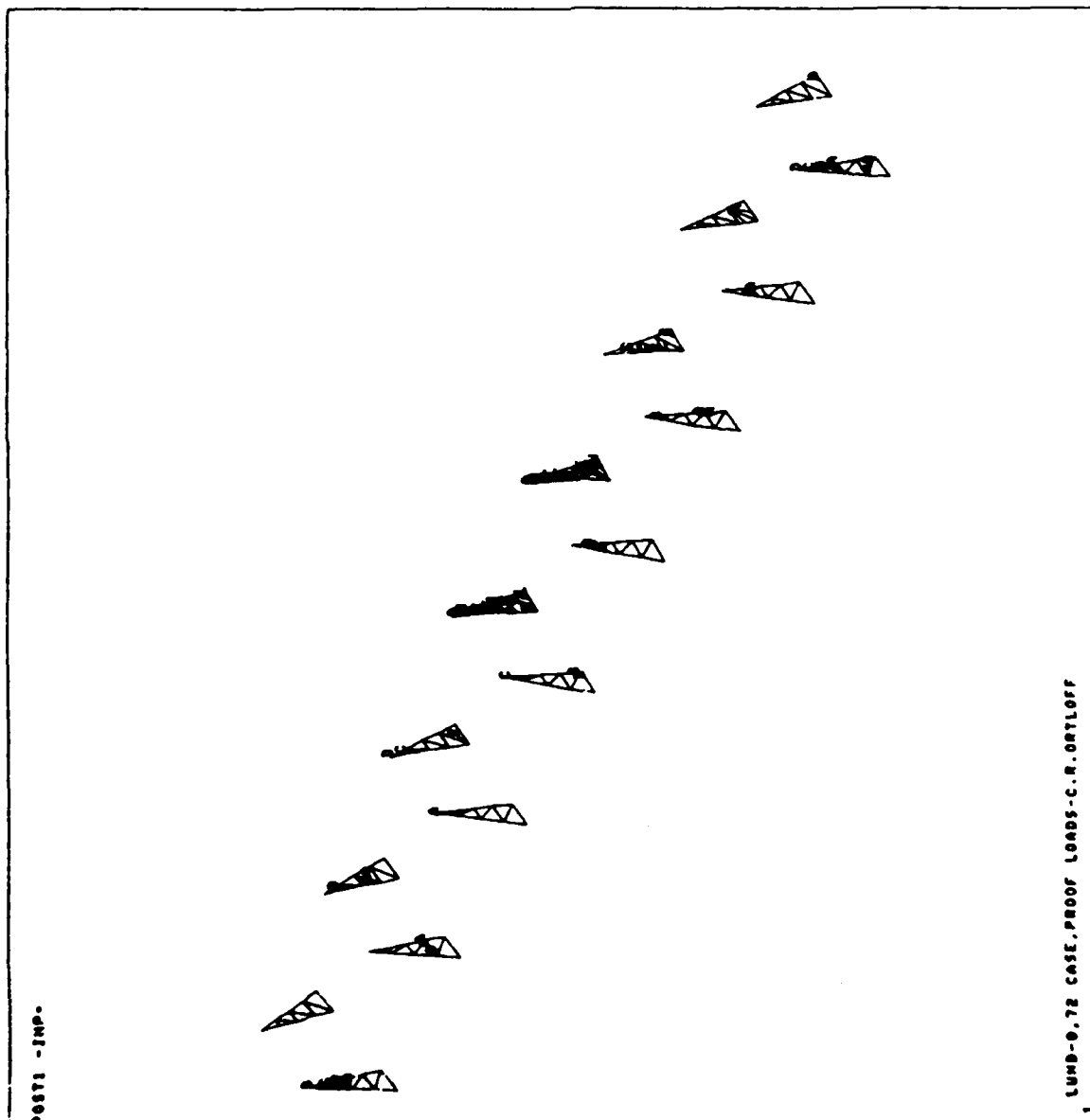
352
 BOTTOM TABS

ANSYS 4.20
 DEC 28 1986
 15:36:05
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.250
 SLOE
 TOP
 ZOOM
 KU=1
 VU=1
 ZU=1
 0.167-13.4
 0.42-4
 0.50-5
 27--9.65
 H870-1.86
 V870-1.88
 HIDDEN
 HX=13004
 HH=672
 A=1220
 B=2312
 C=3494
 D=4456
 E=5528
 F=6600
 G=7772
 H=8864
 I=9956
 J=11048
 K=12140

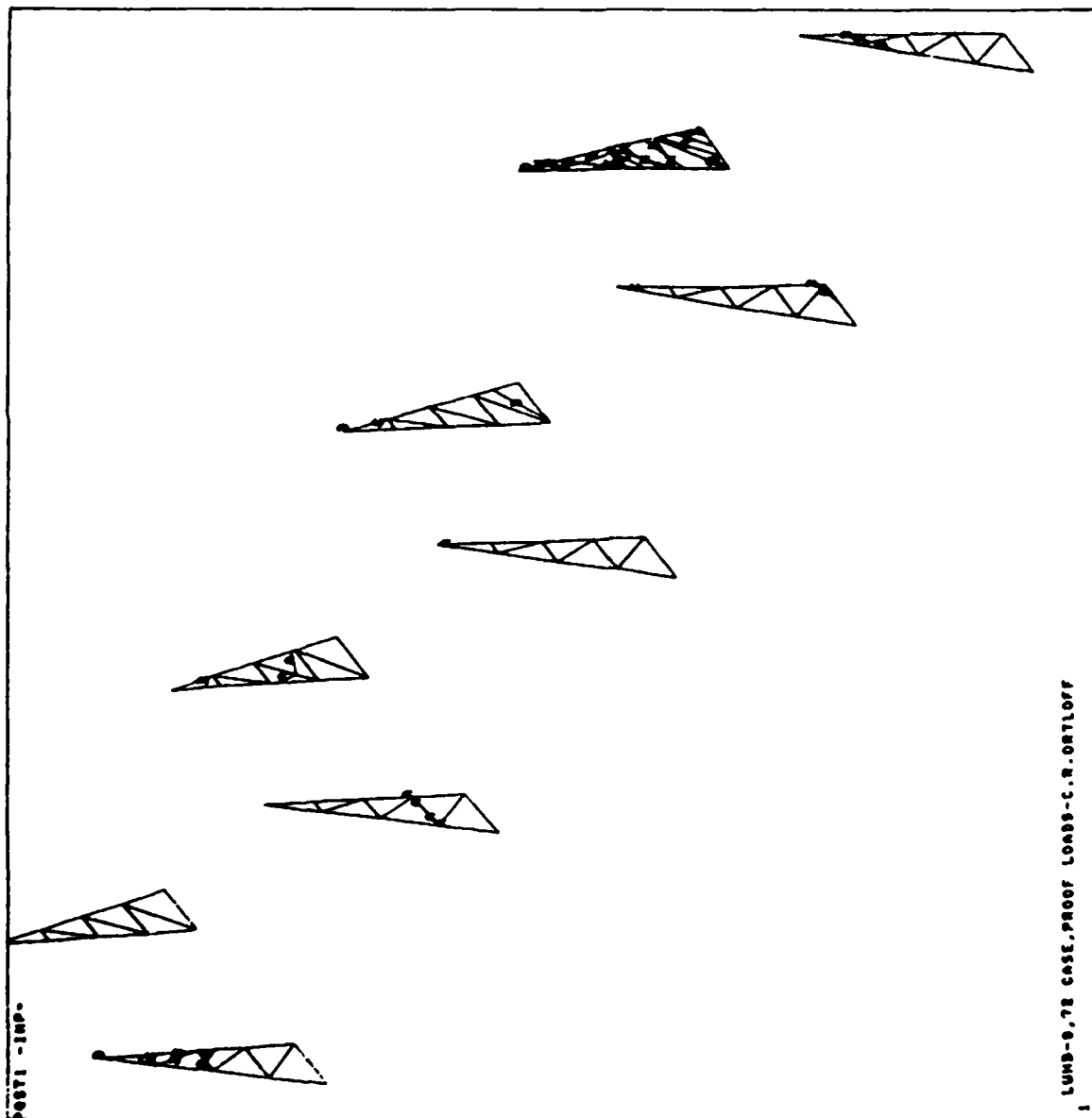


205.3
 TOP

ANSYS 4.20
 DEC 28 1986
 15:38:00
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.888
 SIZE
 TOP
 ZOOM
 KU=1
 VU=1
 2U=1
 DIST=88.8
 XF=88.8
 VF=2.55
 ZF=2.2
 KRT0=1.96
 VRT0=1.88
 HIDDEN
 RM=1128
 MM=219
 A=888
 B=1588
 C=2877
 D=2866
 E=2655
 F=4244
 G=5033
 H=5722
 I=6411
 J=7100
 K=7788
 L=8478
 M=9167
 N=9856
 O=10545



ANSYS 4.20
 DEC 20 1986
 15:38:00
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.250
 QLOC
 TOP
 ZOOM
 MU=1
 VU=1
 ZU=1
 0 DISY=46.3
 0 UF=36.6
 0 VF=9.58
 0 ZF=14.6
 HRT0=1.98
 VRT0=2.47
 MIDDEN
 RM=11289
 RM=351
 A=809
 B=1500
 C=2277
 D=2066
 E=3655
 F=4344
 G=5033
 H=5722
 I=6411
 J=7100
 K=7789
 L=8478
 M=9167
 N=9856
 O=10545



ANSYS 4.20
 DEC 20 1986
 15:38:44
 POST1 STRESS

STEP=1
 ITER=1
 TIME=.280
 SLOC
 TOP

ZOOM
 KU=1
 YU=1
 ZU=1

0 0107-42.8
 1 XF-72.5
 2 YF-6.41
 3 ZF-7.48

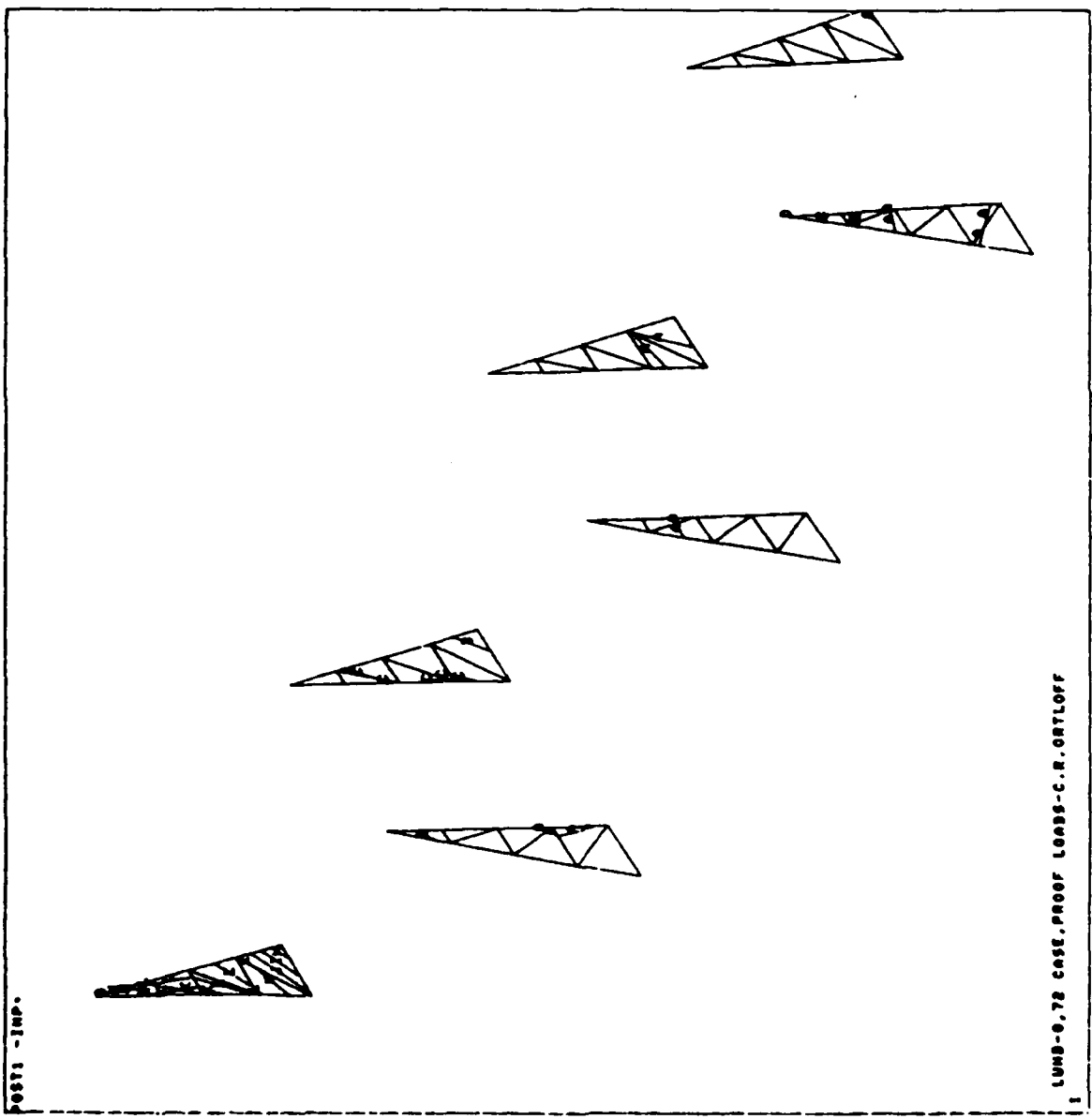
XRT0-2.20
 VRT0-2.47
 MIBDEM
 RM-10000
 RM-215

A-899
 B-1588
 C-2277
 D-2866
 E-2655

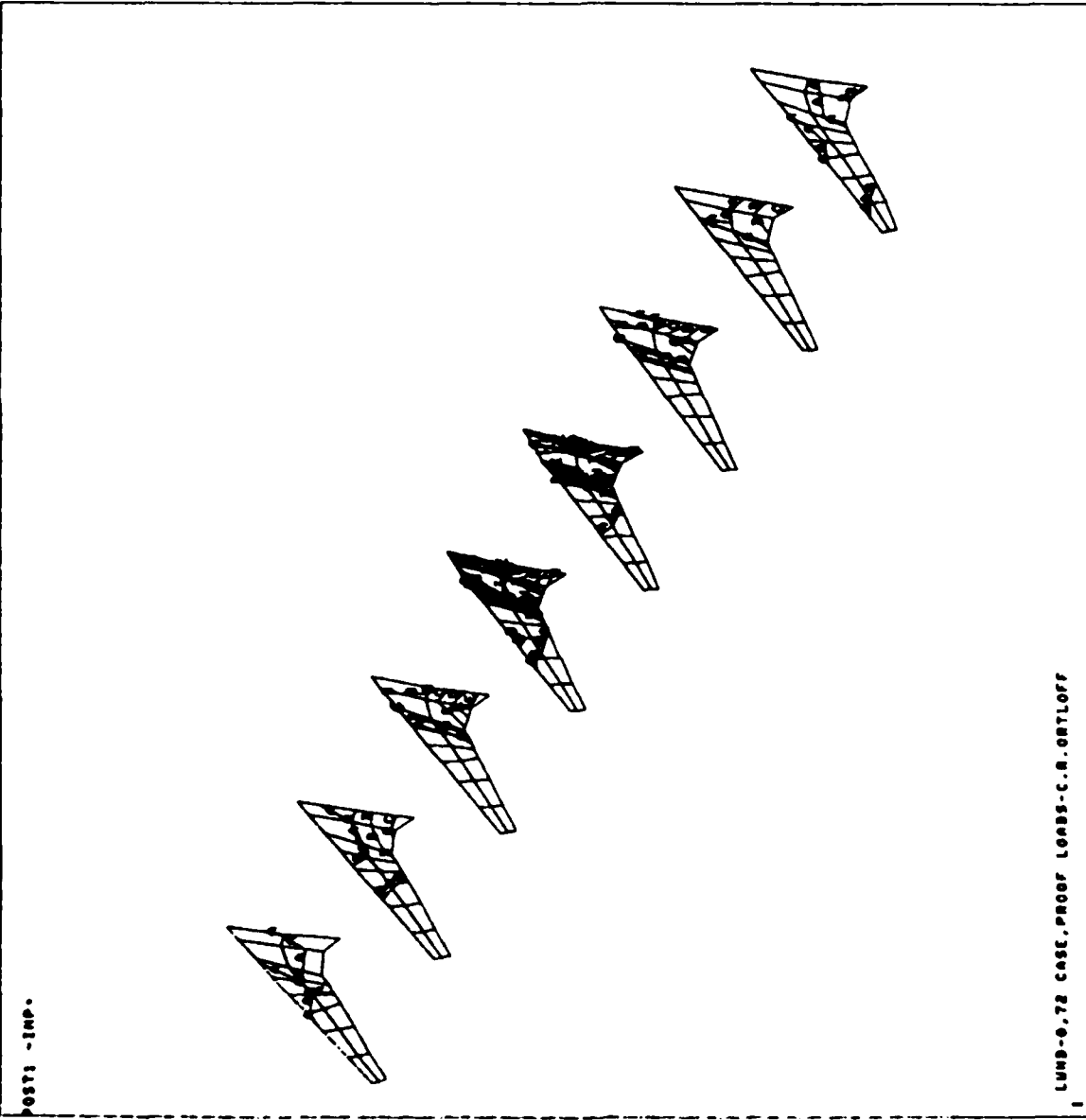
F-4244
 G-5033
 H-5722
 I-6411
 J-7100

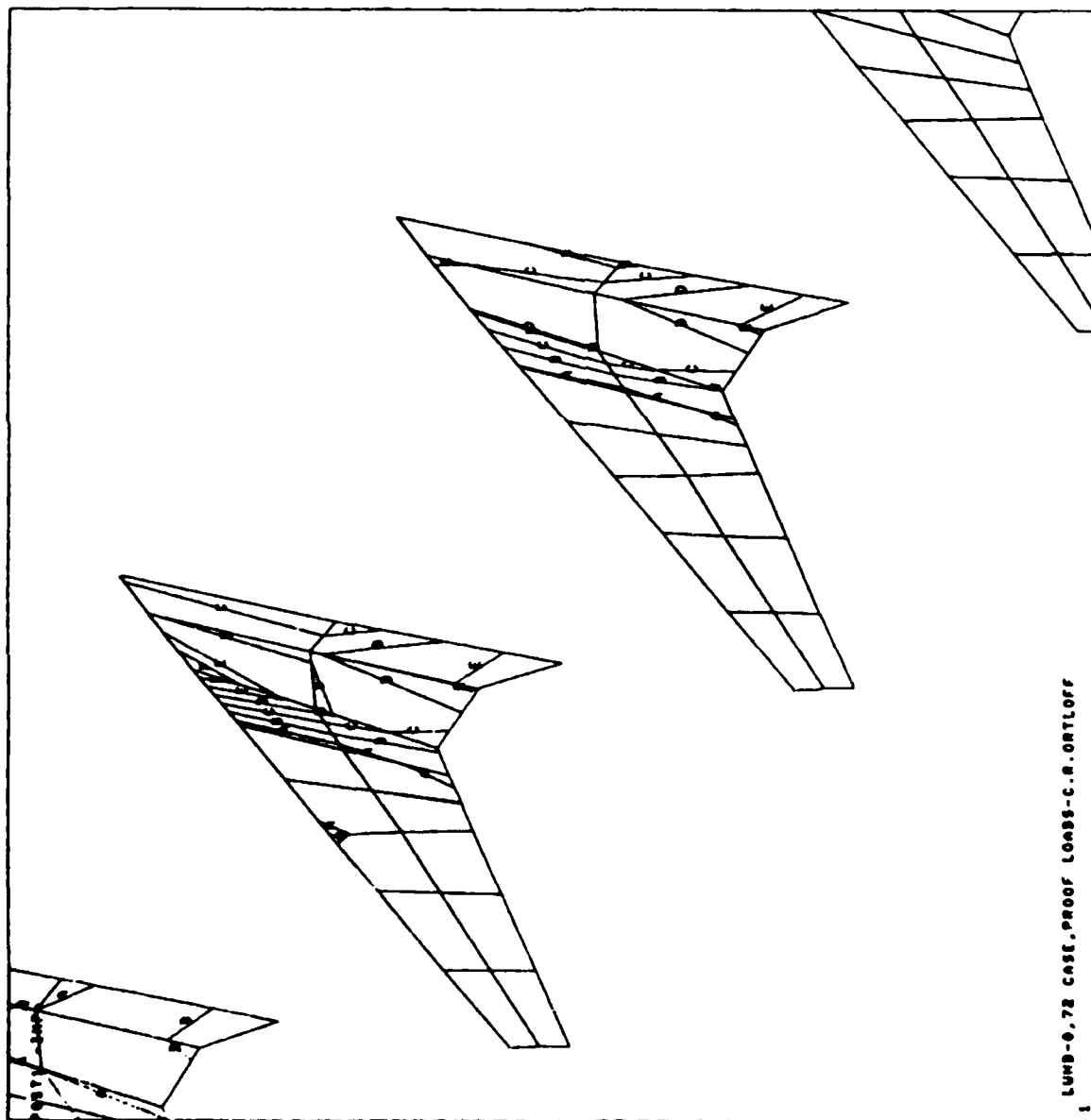
K-7789
 L-8478
 M-9167
 N-9856

O-10545



ANSYS 4.20
 DEC 20 1986
 15:40:03
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.250
 SICE
 TOP
 ZOOM
 ZU=1
 VU=1
 ZU=1
 DIST=112
 XF=58.3
 YF=-1.67
 ZF=5.33
 XRT0=2.20
 YRT0=2.47
 HIDDEN
 RM=18719
 RM=202
 A=1355
 B=2513
 C=3671
 D=4020
 E=5987
 F=7145
 G=8303
 H=9451
 I=10619
 J=11777
 K=12935
 L=14093
 M=15251
 N=16409
 O=17567



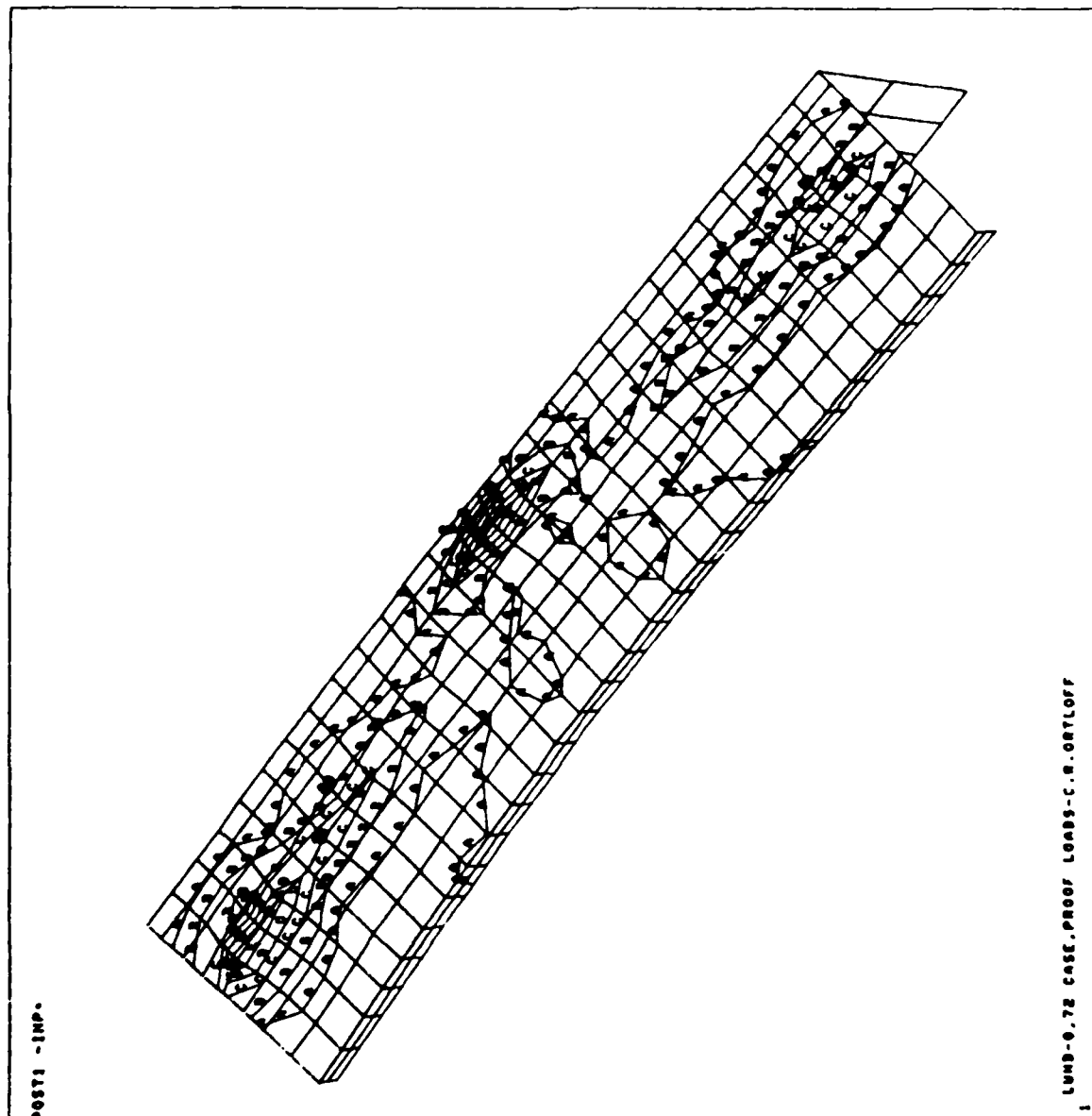


```

      ANSYS      4.20
      DEC 26 1986
      15:00:37
      POST1 STRESS
      STEP=1
      ITER=1
      TIME=.208
      SLOC
      TOP
      ZOOM
      KU=1
      VU=1
      ZU=1
      1 157-38.2
      2 KP-84.2
      3 VP--2.95
      4 ZF--.73
      5 KR70-2.28
      6 VR70-3.18
      7 MIDCM
      8 RX-18719
      9 RM=0
      10 A-2846
      11 B-492
      12 C-8138
      13 D-10784
      14 E-13430
      15 F-15076

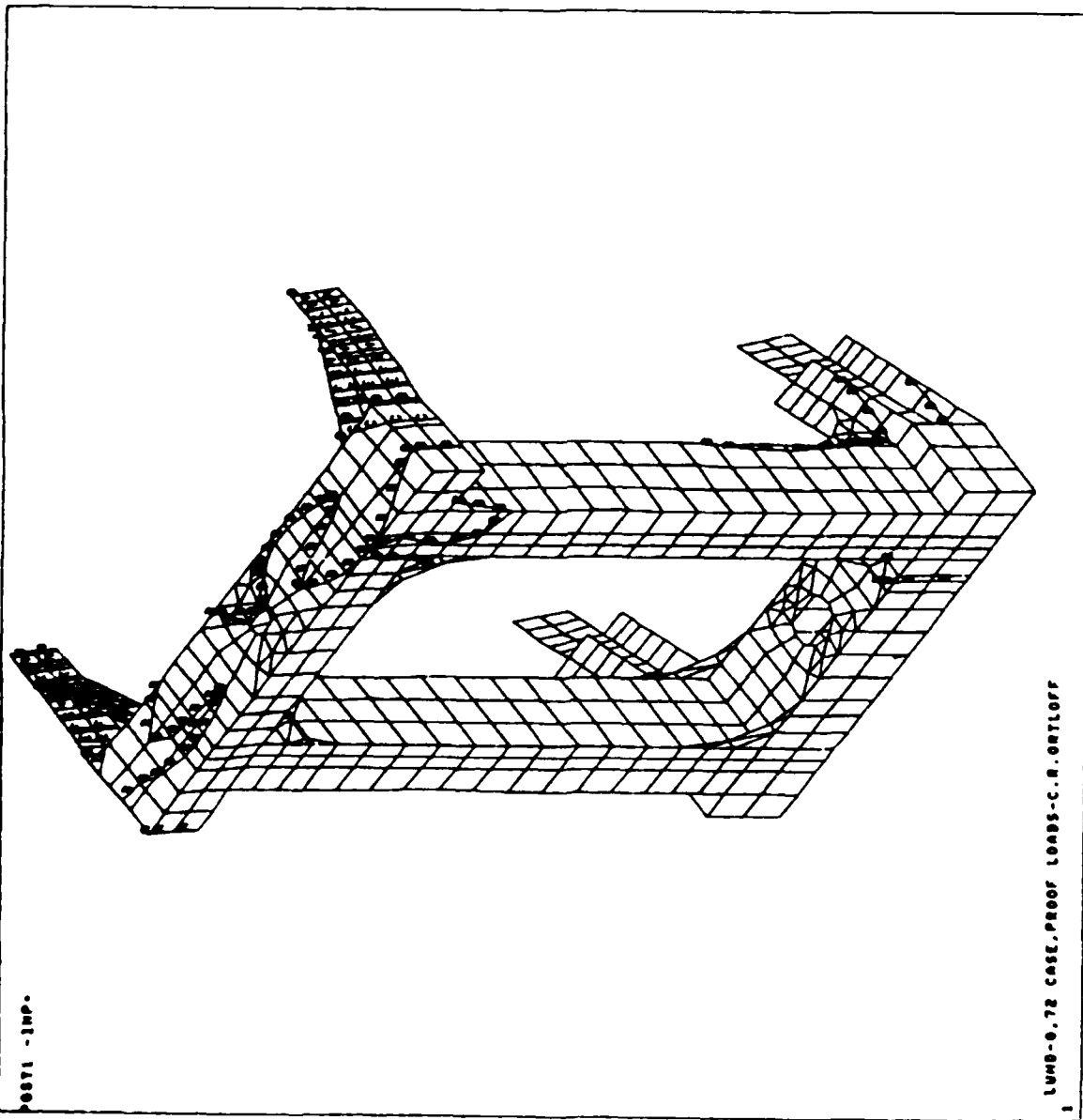
```

ANSYS 4.20
 DEC 28 1988
 15:42:05
 POST1 STRLESS
 STEP=1
 ITER=1
 TIME=.250
 SLOC
 TOP
 ZOOM
 NU=1
 VU=1
 ZU=1
 DIS1=112
 WF=62.3
 VF=-1.67
 ZF=5.33
 MBTO=2.20
 VBTO=3.18
 HIDDEN
 MX=10351
 MM=220
 A=1908
 B=3507
 C=5206
 D=6975
 E=8664



ANSYS 4.20
 DEC 20 1986
 15:40:42
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.000
 UV
 01891 NODAL

 ZOOM
 ZU=1
 VU=1
 ZW=1
 DIST=100
 XF=54.0
 YF=33.0
 ZF=-8.01
 XRT0=8.20
 YRT0=3.10
 WIDEN
 RM=1.12
 RM=-.00223
 A=0
 B=.08
 C=.16
 D=.24
 E=.32
 F=.4
 G=.48
 H=.56
 I=.64
 J=.72
 K=.8
 L=.88
 M=.96
 N=1.04
 O=1.12

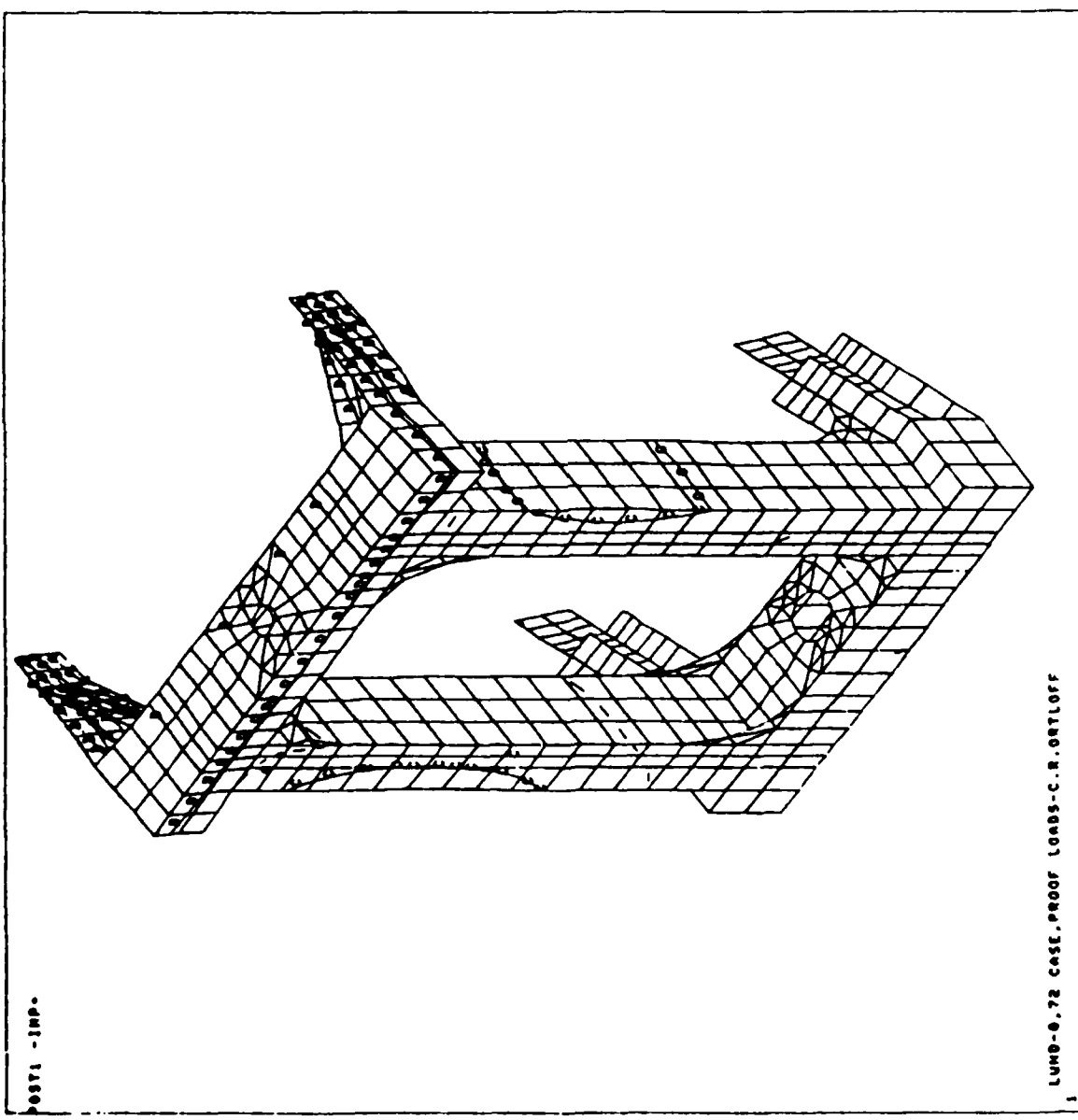


```

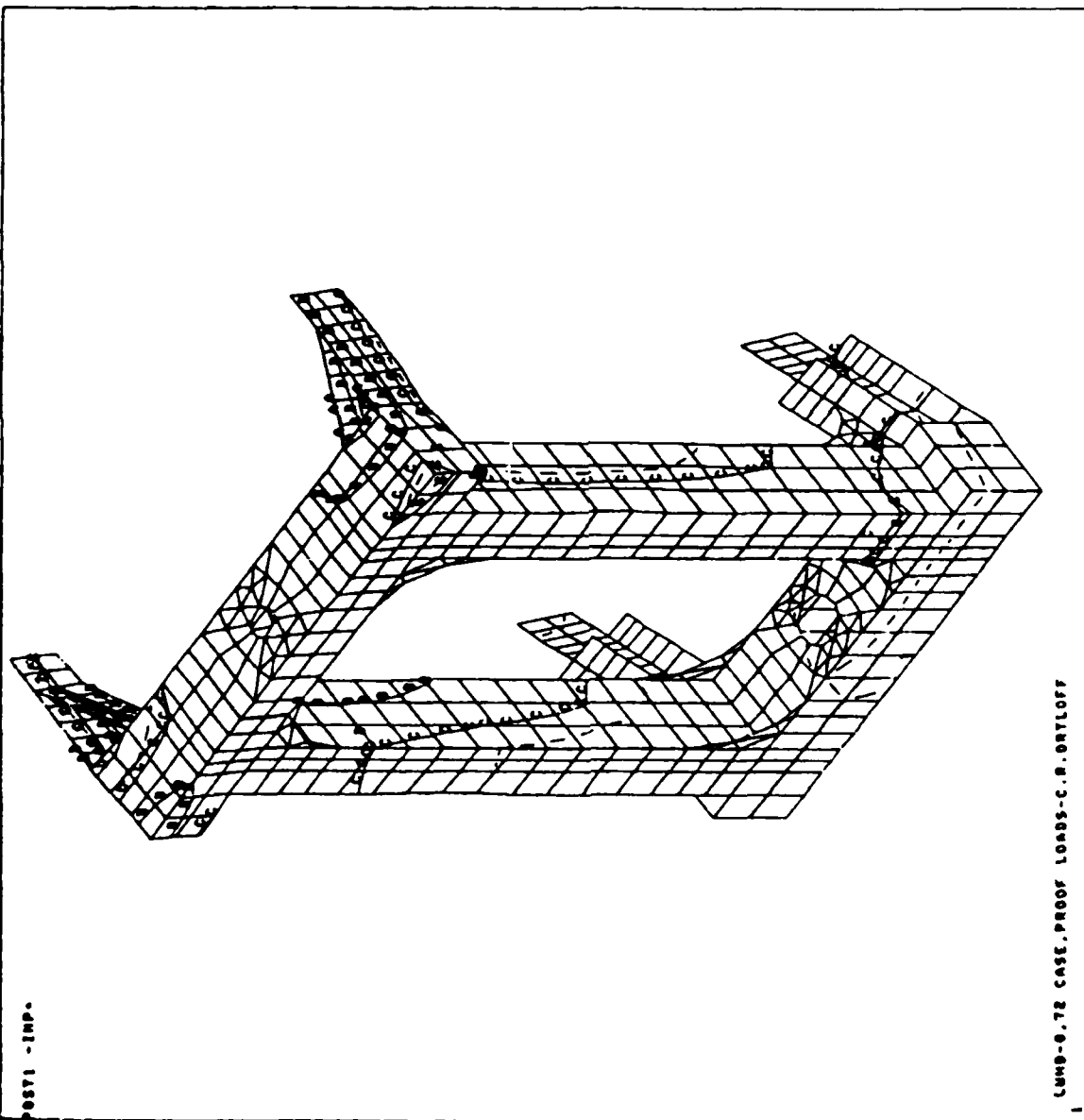
ANSYS 4.20
DEC 20 1986
15:40:10
POST1, STRESS
STEP=1
ITER=1
TIME=.258
U2
DISPL MODAL

ZOOM
XU=1
VU=1
ZU=1
DISP=100
XZ=54.0
VZ=23.0
ZF=-8.01
XROT=2.20
VROT=3.10
MIDSE
RX=.166
RY=-.302
RZ=-.210
B=-.110
C=-.0170
D=-.0022

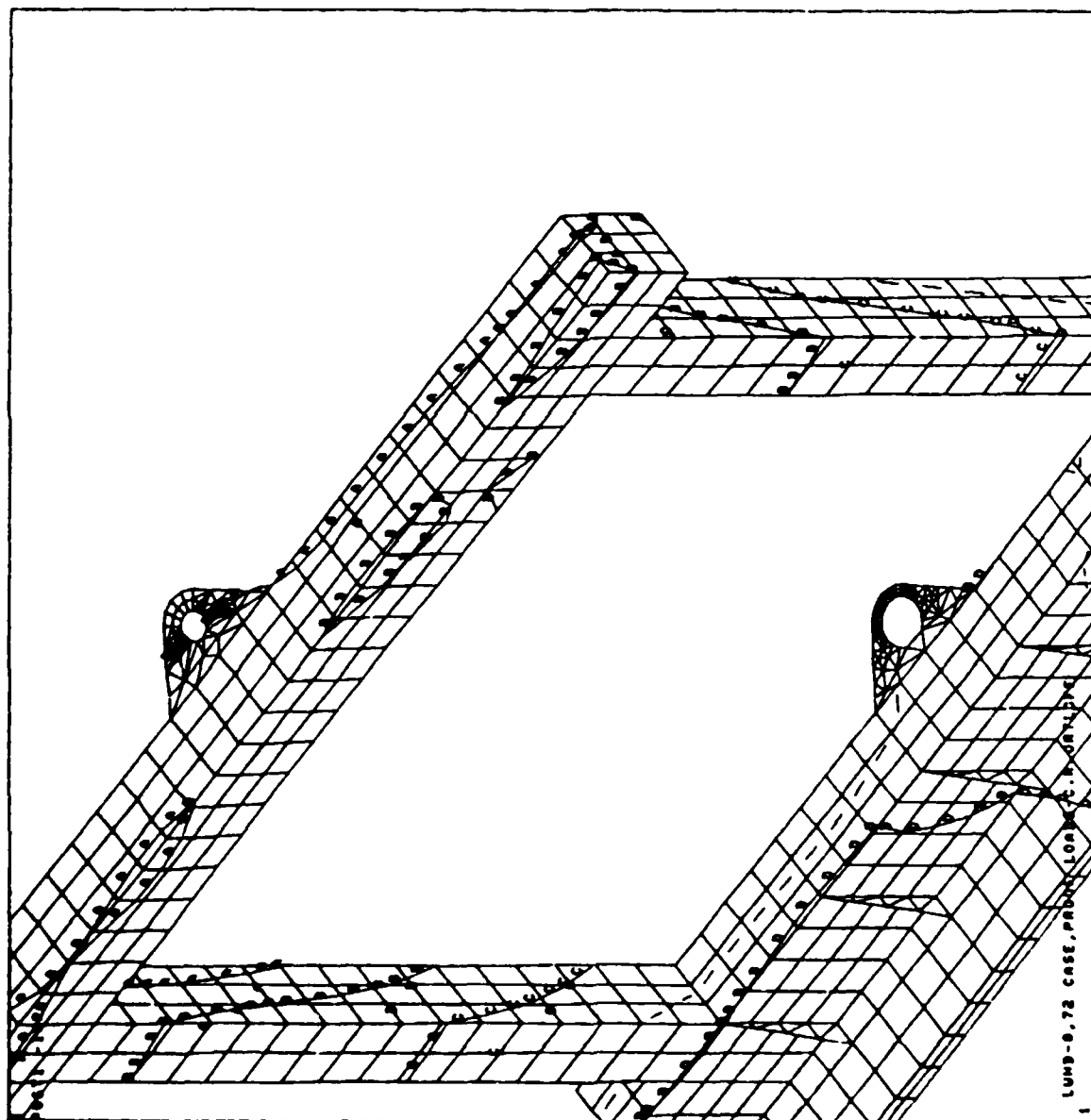
```



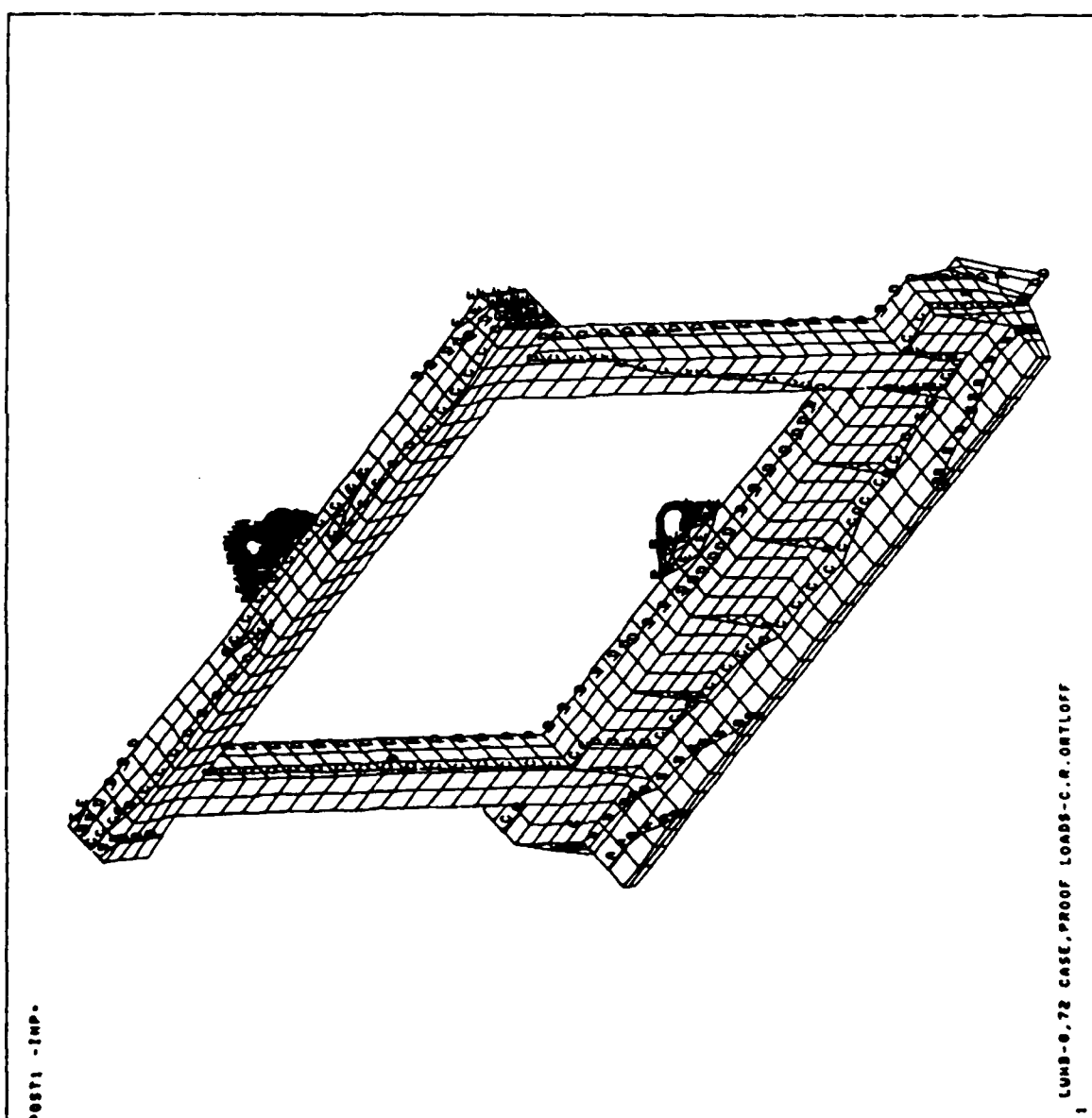
ANSYS 4.2B
 DEC 28 1985
 15:03:20
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.388
 UN
 DISPL MODAL
 ZOOM
 KU=1
 VU=1
 ZU=1
 1 8157.109
 2 8F=54.9
 3 VF=33.9
 4 2F=-8.01
 5 KATO=2.29
 6 VATO=3.18
 7 HIDDEN
 8 HX=.0201
 9 HX=.0512
 10 A=-.0456
 11 B=-.0255
 12 C=-.00556
 13 D=.0144



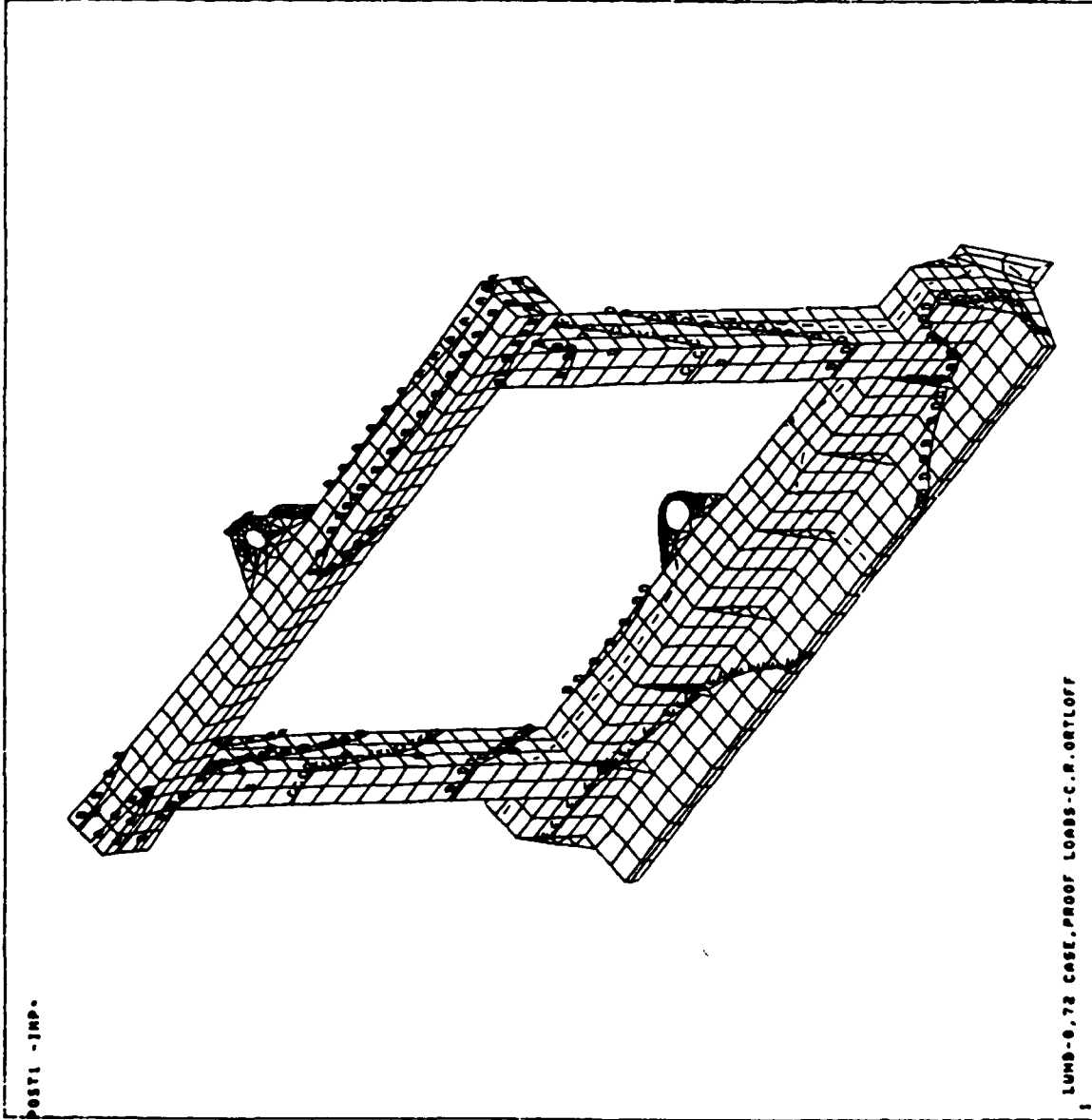
ANSYS 4.28
 DEC 28 1986
 15157106
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.858
 UX
 DISPL NODAL
 ZOOM
 XU=1
 YU=1
 ZU=1
 0 DISPL=100
 0 MF=54.8
 0 VF=33.8
 0 ZF=8.01
 XRT0=8.29
 YRT0=3.18
 M189EN
 RX=.00787
 RY=-.0218
 A=-.0158
 B=-.0089
 C=-.0038
 D=-.0021



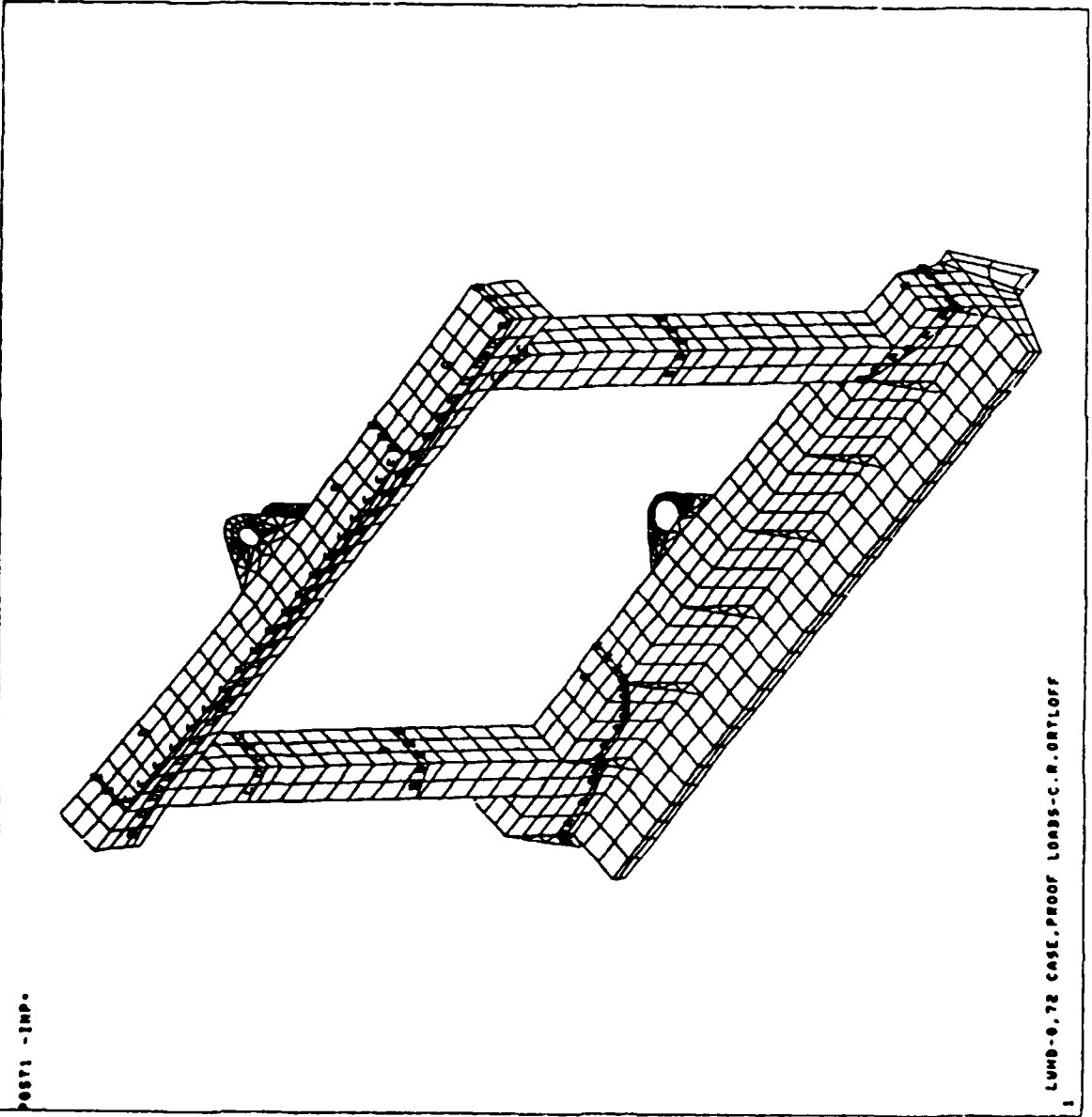
ANSYS 4.20
DEC 20 1986
16:03:00
POST1 STRESS
STEP=1
ITER=1
TIME=.000
UV
DISPL NODAL
ZOOM
XU=1
YU=1
ZU=1
DIST=100
XF=51.2
YF=27.7
ZF=4.17
XRT0=2.29
YRT0=3.18
HIDDEN
MX=-.142
MY=-.0459
MZ=-.0361
S=-.0241
C=-.0121
D=-.00013
E=.0119
F=.0239
G=.0359
H=.0479
I=.0599
J=.0719
K=.0839
L=.0959
M=.108
N=.12
O=.132



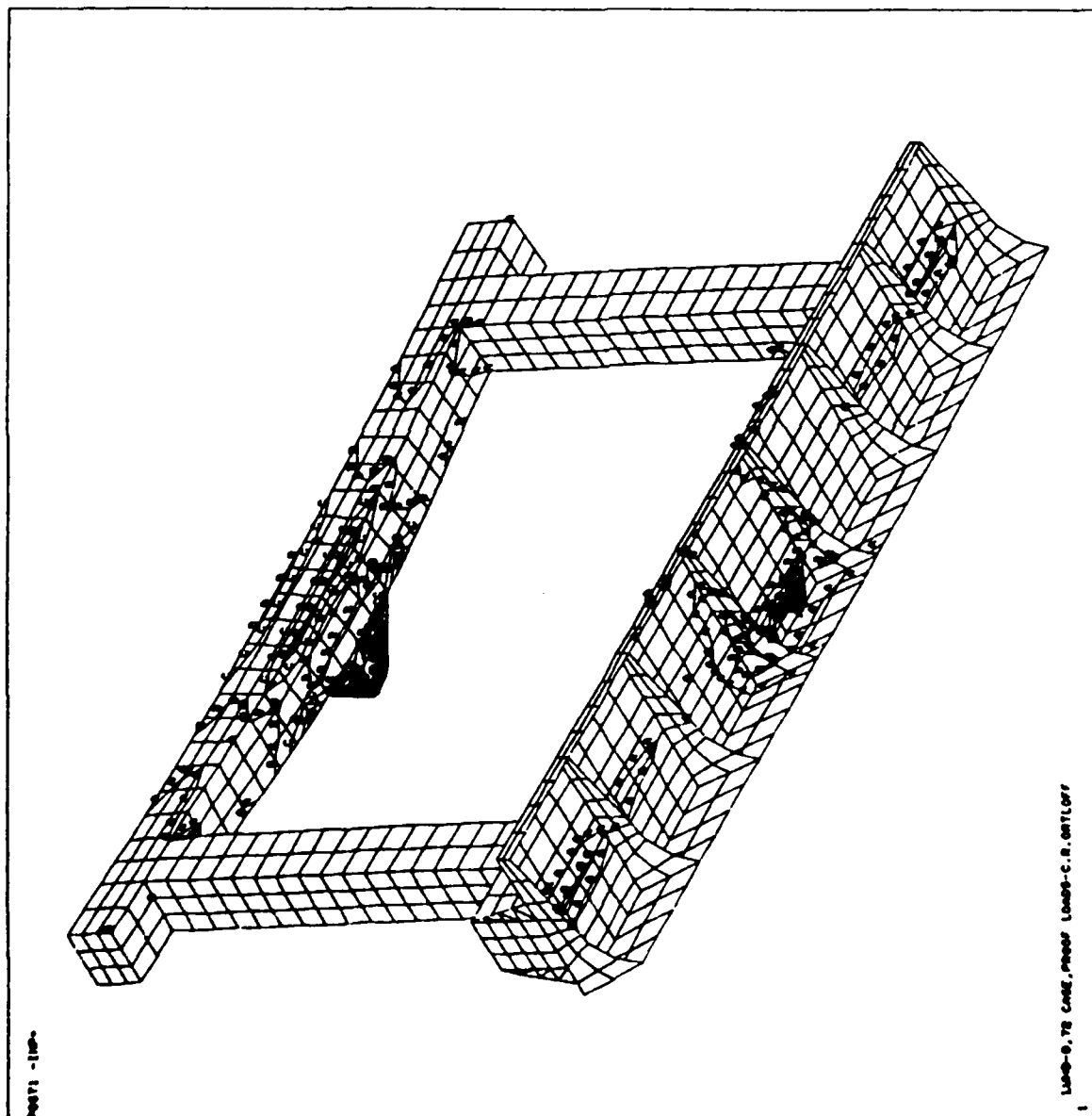
ANSYS 4.20
 DEC 28 1986
 16123120
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.250
 UX
 DISPL MODAL
 ZOOM
 MU=1
 VU=1
 ZU=1
 Z DIST=100
 Z XF=51.2
 Z VF=27.7
 Z ZF=4.17
 XRT0=2.20
 VRT0=3.18
 HIDDEN
 RX=.00004
 RM=.0218
 A=-.0169
 B=-.0119
 C=-.0059
 D=-.0019
 E=.0031



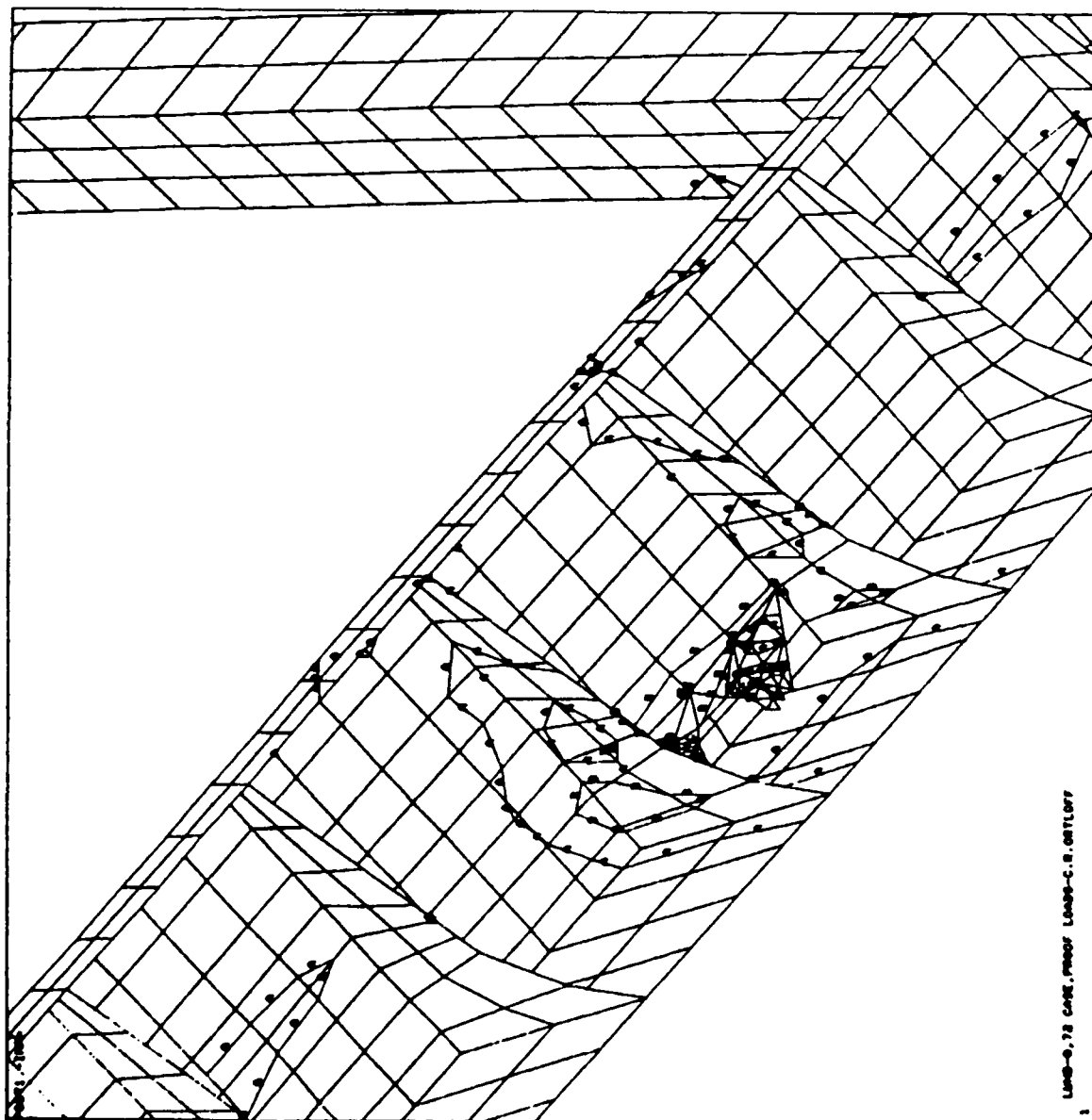
ANSYS 4.20
 DEC 28 1986
 1615183
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.850
 UZ
 DISPL NODAL
 ZOOM
 KU=1
 YU=1
 VU=1
 ZU=1
 1 DIST=100
 2 XF=51.2
 3 YF=27.7
 4 ZF=4.17
 HOTO=2.29
 VOTO=3.18
 MIBDEM
 MX=.267
 MY=0
 MZ=.0337
 B=.0837
 C=.134
 D=.184
 E=.234



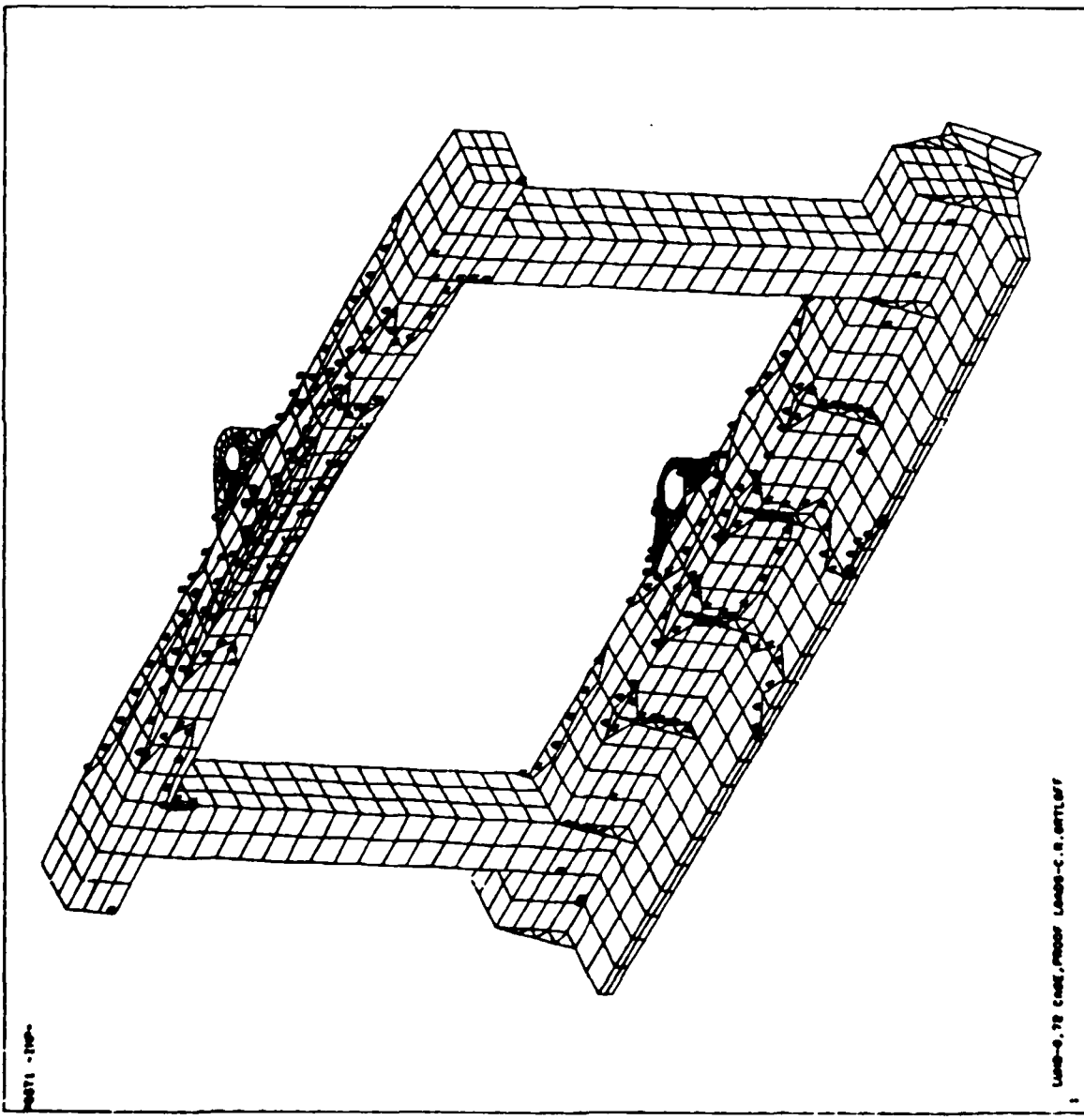
00101 4.00
 DEC 20 1966
 01471.00
 POSTS STRESS
 STEP=1
 ITER=1
 TIME=.031
 0100
 TOP
 10--1
 10--1
 20--1
 0151-55.2
 10-54.2
 10-55.4
 22-4.00
 110000
 00-54.16
 00-345
 A-0023
 B-17702
 C-20301
 D-20400
 E-03720



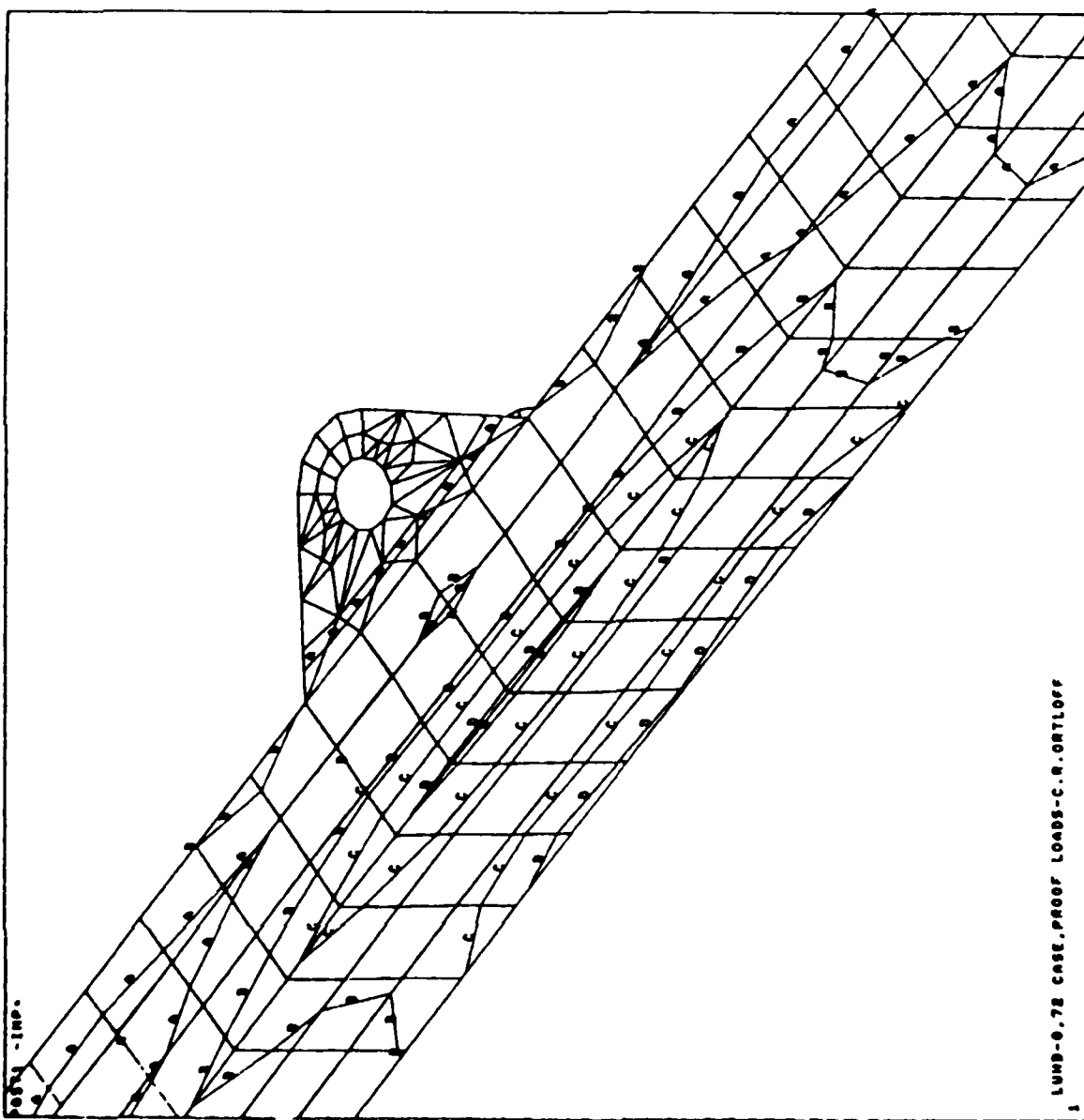
1100-0.78 CASE, PRESS LOADS-C.B. 0011 OFF

[illegible]

000148 4.30
 DEC 20 1966
 10100.17
 00071 01ME06
 STEP=1
 ITER=1
 TIME=.031
 SIZE
 TOP
 10=1
 10=1
 20=1
 0151-06.6
 17-01.2
 17-07.7
 20-4.17
 1100EN
 10=02416
 10=348
 0=0007
 0=17708
 0=02301
 0=35000
 0=43730

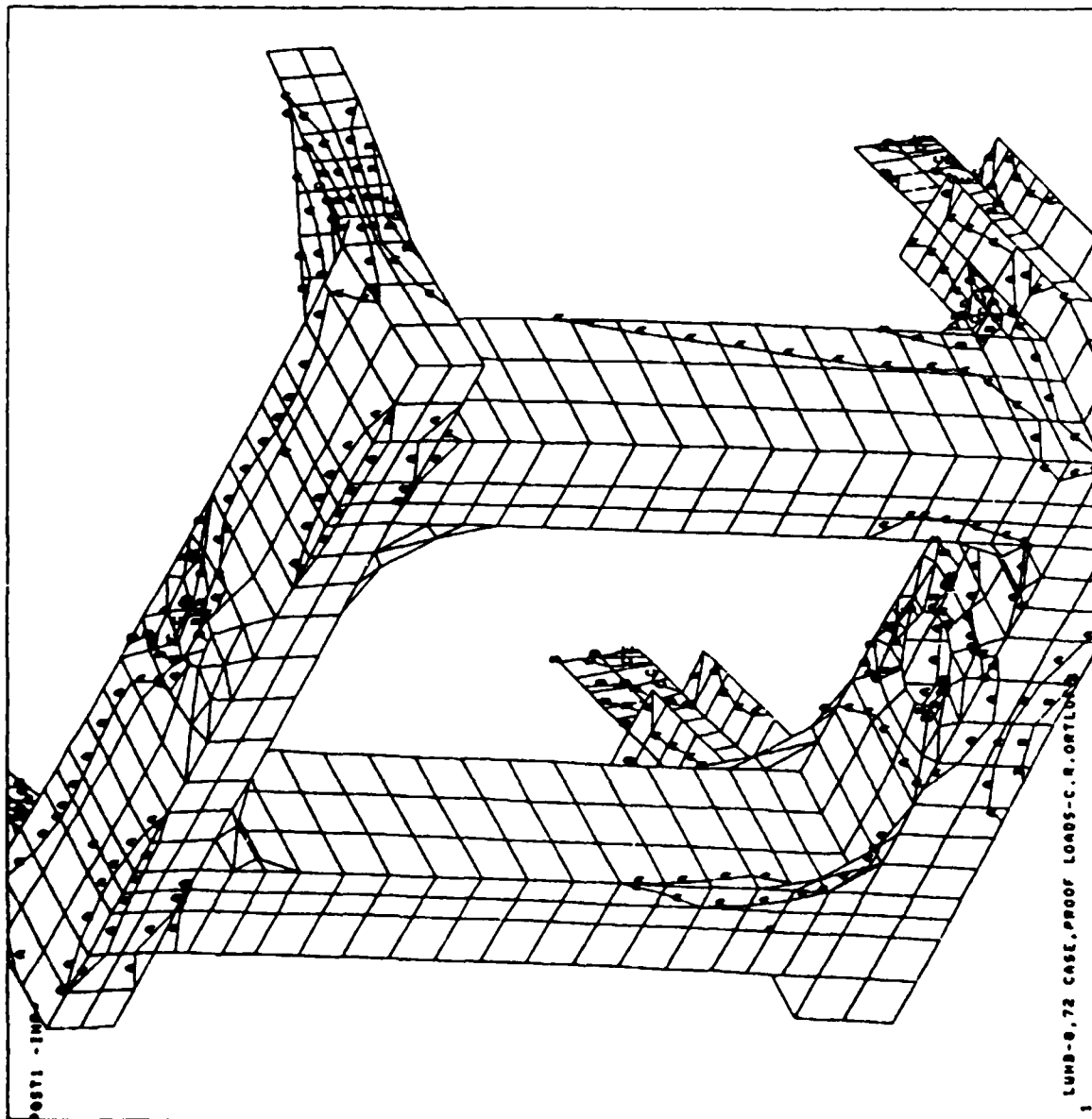


ANSYS 4.20
 DEC 20 1986
 10100117
 POST1 STRESS
 STEP=1
 LAYER=1
 VINC=.031
 SLOC
 TOP
 ZOOM
 KU=1
 VU=1
 ZU=1
 1 DISP=20.8
 2 SF=43.9
 3 VF=48.3
 4 ZF=10.8
 VRT0=1.36
 M100EN
 MX=49942
 MY=0
 A=9023
 B=17702
 C=26381
 D=35060
 E=43730

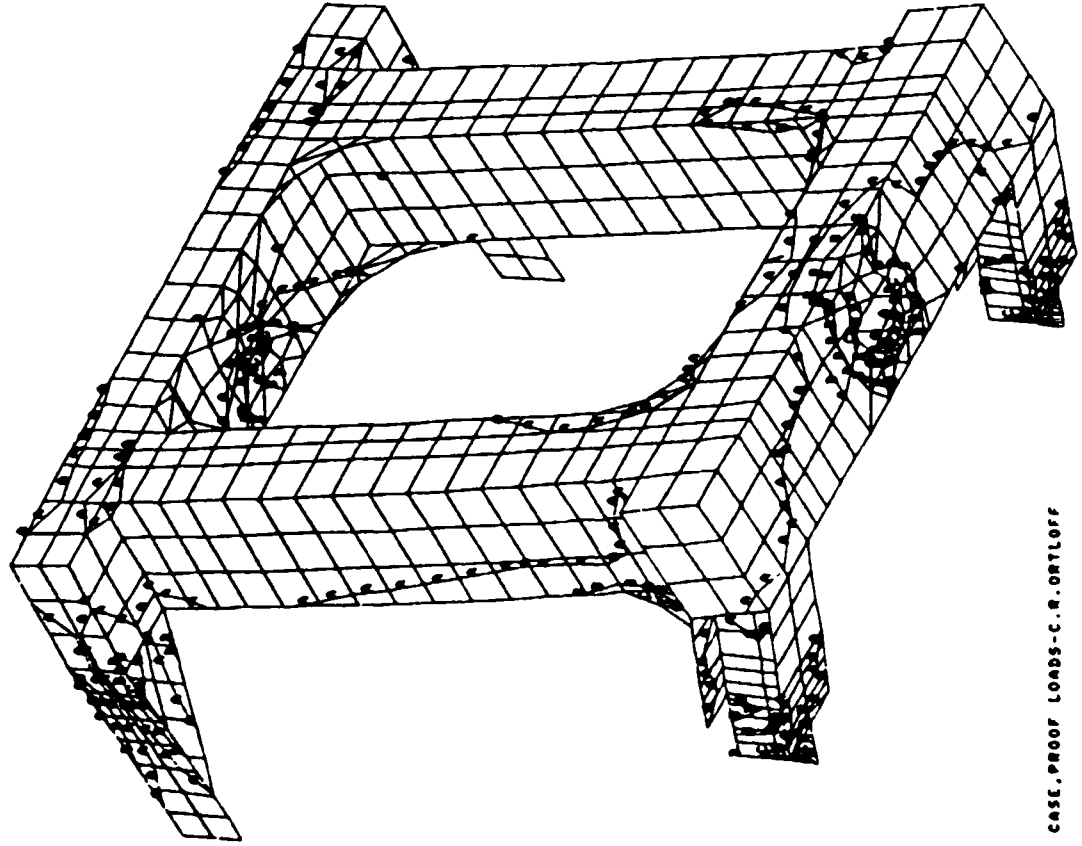


1 LUMB=0.72 CASE,PROOF LOADS-C.R.ORTLOFF

ANSYS 4.20
 DEC 20 1985
 10:33:00
 POST1 STRESS
 STEP=1
 TIME=1
 TIME=0.031
 SIDE
 TOP
 KU=1
 YU=1
 ZU=1
 8 8187.26.3
 8 87.53
 8 87.32.8
 8 87.10.3
 MIDDLE
 RM=155611
 RM=8
 A=27994
 B=53518
 C=79042
 D=104566
 E=130990



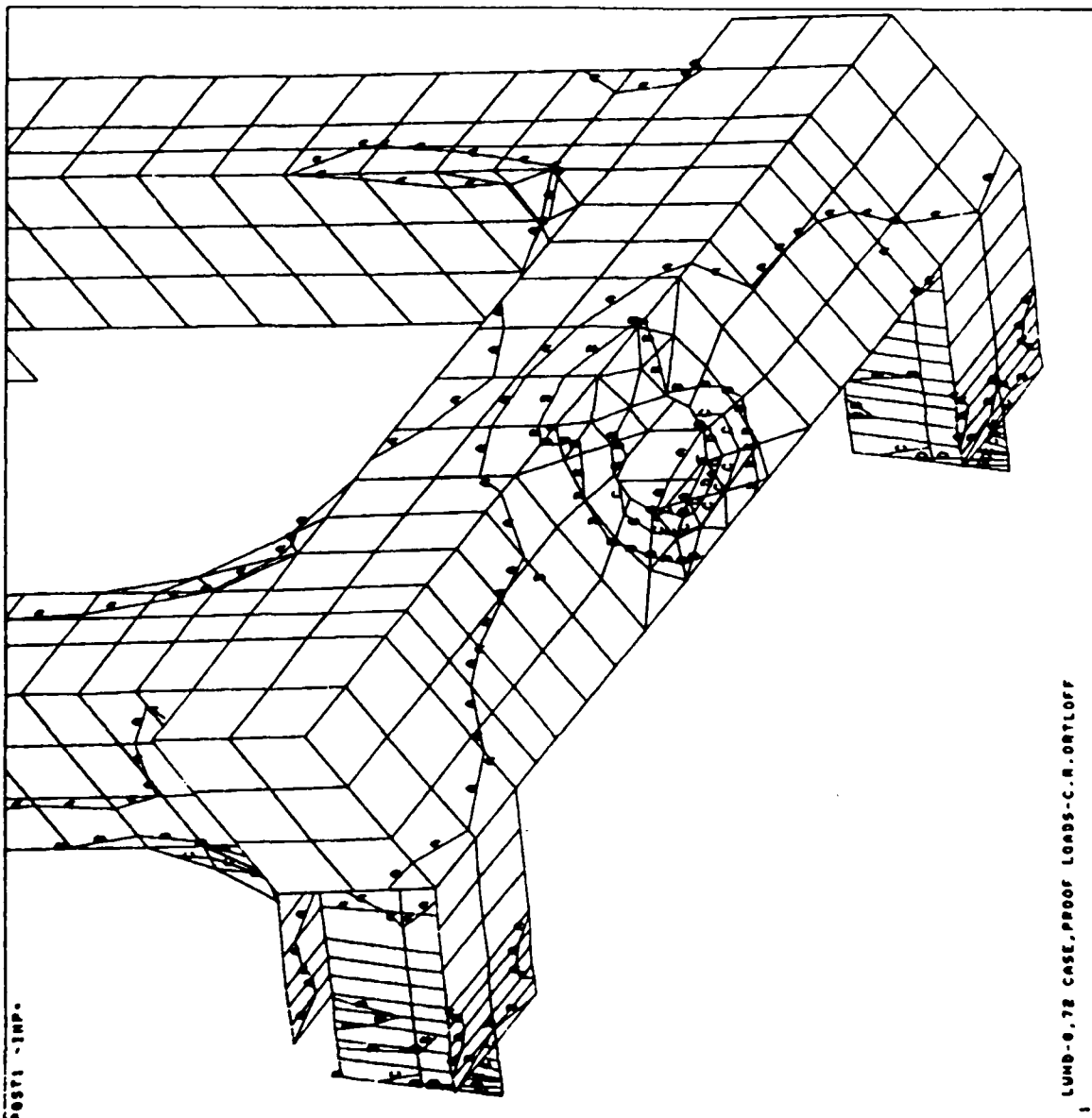
ANSYS 4.80
DEC 20 1986
10:38:00
POST1 STRESS
STEP=1
ITER=1
TIME=.031
SIZE
TOP
XU=-1
VU=-1
ZU=-1
DIST=32.7
XF=51.8
VF=36.8
ZF=-8.87
HIDDEN
MX=185811
MY=2472
M=27994
S=53518
C=78942
D=104566
E=130886



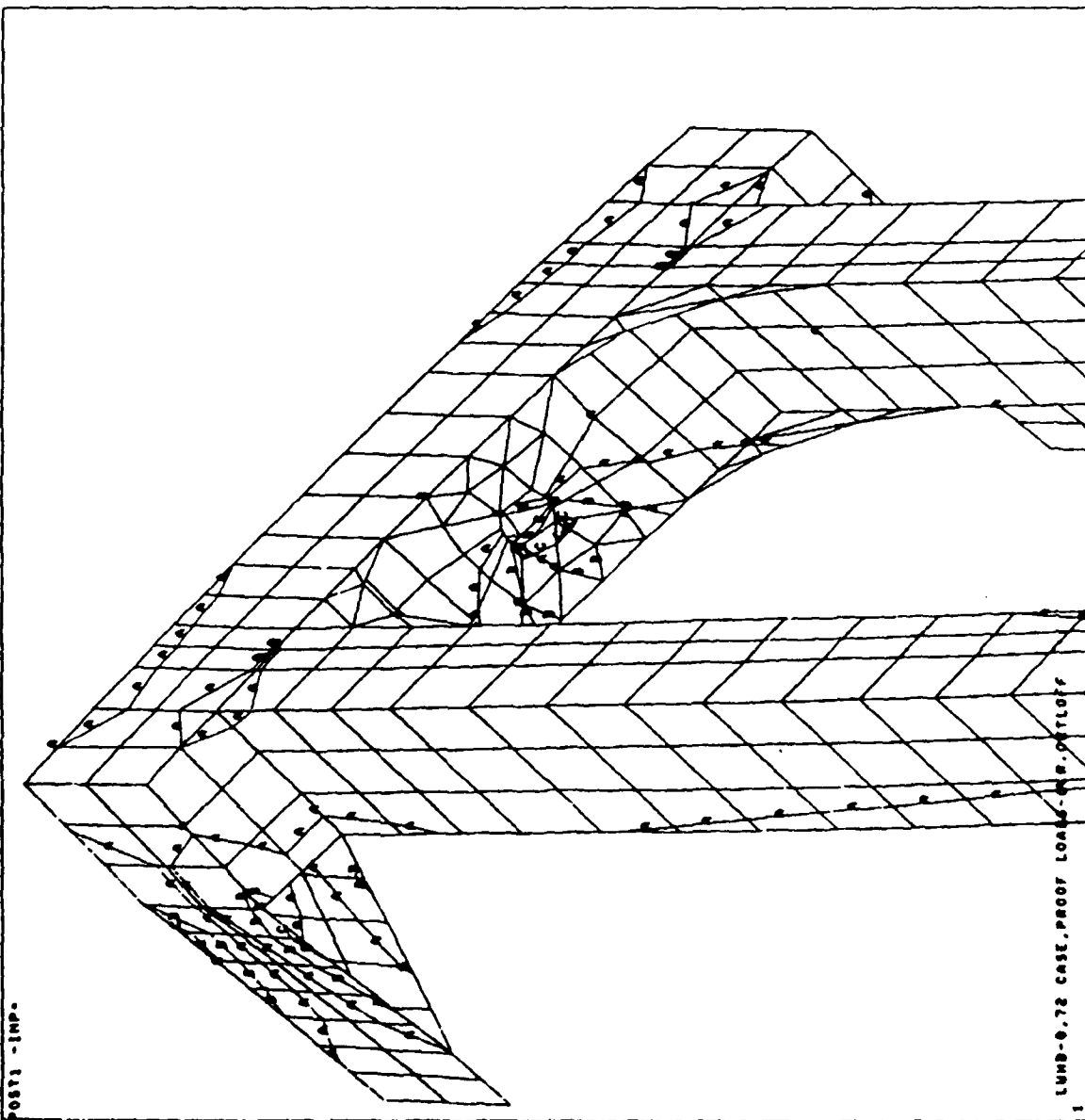
POST1 - ENP.

1 LUMB=0.72 CASE, PROOF LOADS-C.R.ORTLOFF

ANSYS 4.20
 DEC 20 1986
 10:30:00
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.031
 SICE
 TOP
 ZOOM
 KU=-1
 VU=-1
 ZU=1
 1 DIST=21.4
 2 KF=58.7
 3 VF=21.2
 4 ZF=-15.5
 5 VRT0=1.4
 MIDDEN
 RX=155611
 RM=0
 A=27894
 B=53518
 C=79042
 D=104566
 E=130000

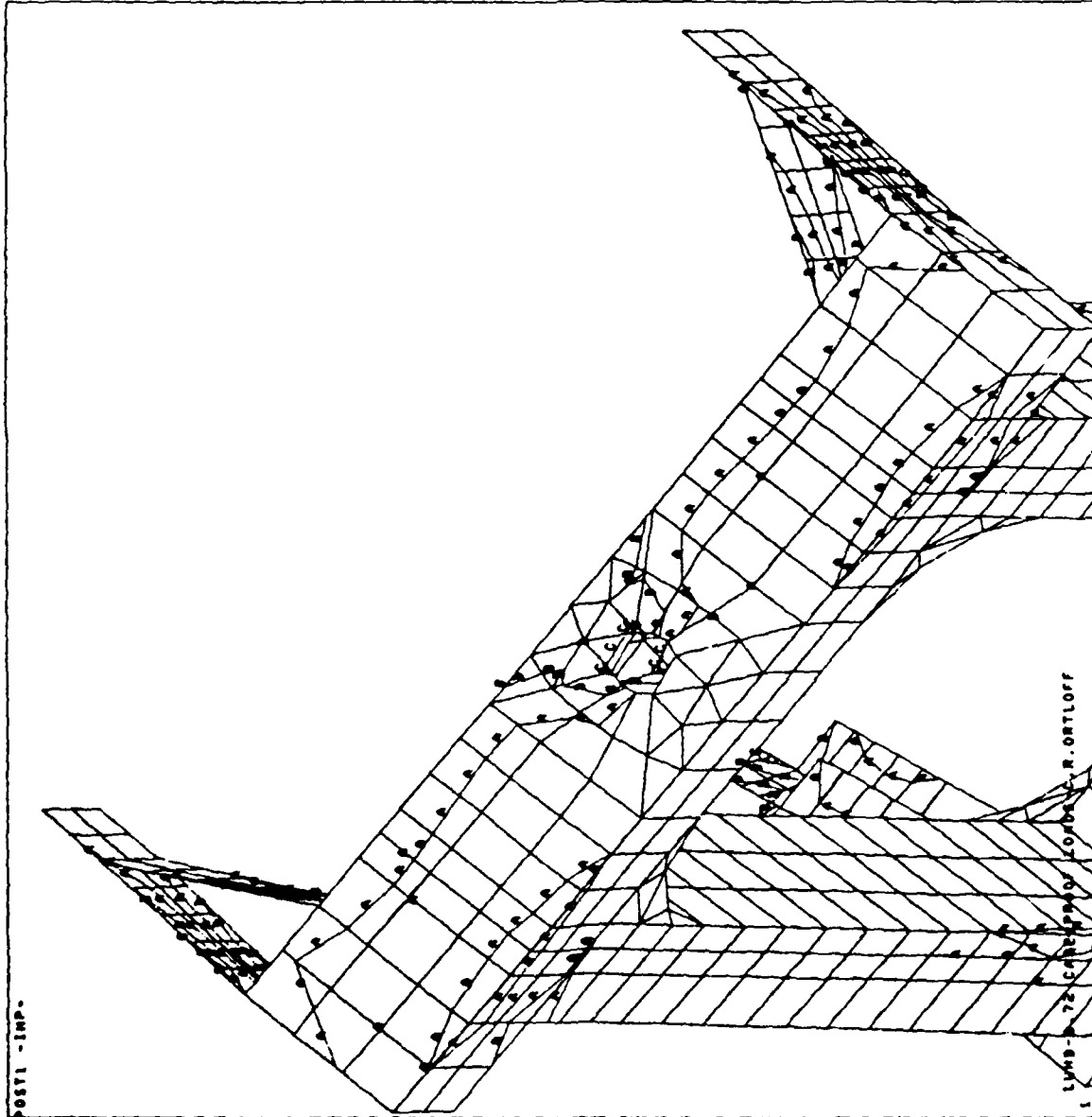


ANSYS 4.20
 DEC 29 1986
 10:43:05
 POST1 STRESS
 STEP=1
 LAYER=1
 TIME=.031
 SIZE
 TOP
 ZOOM
 KU=-1
 YU=-1
 ZU=-1
 2 DIST=26.4
 2 WF=46.2
 2 VF=46.6
 2 ZF=2.5
 VROT=1.78
 HIDDEN
 NX=94576
 NN=6
 A=27994
 B=53518
 C=78942



ANSYS 4.20
 DEC 29 1986
 18148157
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.031
 SICE
 TOP

ZOOM
 XU=.4
 VU=1
 ZU=.5
 DIST=34.0
 XE=48.5
 YF=42.3
 ZF=17.8
 XRT0=1.42
 YRT0=1.78
 MIDDEN
 MX=145769
 MY=0
 A=27884
 B=53518
 C=79842
 D=184566
 E=130880



PRINT ELEMENT STRESS ITEMS PER ELEMENT

88888 POST1 ELEMENT STRESS LISTING 88888

| LOAD STEP | 1 | ITERATION | 1 | SECTION | 1 |
|-----------|-------------|-----------|---------|---------|---|
| TIME | 0.31000E-01 | LOAD CASE | 1 | | |
| ELEM | SDIR | SBZ | SBVI | SBZ2 | |
| 3078 | 149.62 | 1478.4 | 353.66 | -339.58 | |
| 3079 | 445.58 | 1433.5 | 359.55 | -787.77 | |
| 3080 | 6049.2 | -318.79 | -212.91 | 180.38 | |
| 3081 | -2727.1 | -109.24 | 1807.1 | -32.389 | |
| 3082 | -226.66 | 45.056 | -867.75 | -75.778 | |
| 3083 | 1198.2 | -56.221 | -1446.6 | 31.046 | |
| 3084 | 418.48 | 53.446 | 1139.8 | 186.86 | |
| 3085 | 9885.8 | -205.58 | -208.19 | 65.821 | |
| 3086 | -268.04 | -46.994 | 1488.2 | -60.563 | |
| 3089 | 6171.1 | -266.93 | 804.42 | 89.629 | |
| 3090 | -2585.6 | 116.83 | -1773.8 | -294.74 | |
| 3092 | 398.07 | 314.15 | -1671.5 | -84.811 | |
| 3093 | 1242.7 | -15.369 | 1893.7 | -82.344 | |
| 3095 | 3978.4 | 634.20 | 323.62 | -663.90 | |

MORE (YES, NO OR CONTINUOUS).

88888 POST1 ELEMENT STRESS LISTING 88888

| LOAD STEP | 1 | ITERATION | 1 | SECTION | 1 |
|-----------|-------------|-------------|---------|---------|---|
| TIME | 0.31000E-01 | LOAD CASE | 1 | | |
| ELEM | SDIR | SBZ | SBVI | SBZ2 | |
| 3096 | -5208.2 | -120.28 | 548.30 | 422.83 | |
| 3097 | -1631.7 | 1699.2 | -673.75 | -962.76 | |
| 3098 | -8270.7 | -186.03 | -576.64 | 479.43 | |
| 3099 | -2663.5 | 304.19 | -151.16 | -89.250 | |
| 3101 | -5524.2 | 370.20 | -1688.8 | -69.092 | |
| 3106 | -1580.1 | -859.82 | 1646.3 | 1695.4 | |
| 3107 | -3418.9 | 317.34 | 143.65 | -102.70 | |
| 3108 | -8285.3 | 486.71 | 274.40 | -176.32 | |
| 3109 | 4087.6 | 661.66 | -357.39 | -700.09 | |
| 3110 | 9735.2 | -167.53 | 274.45 | 47.817 | |
| 3334 | -247.27 | 0.89786E-01 | 85.434 | 43.750 | |
| 3335 | -370.70 | 3.7816 | 68.338 | 32.046 | |
| 3336 | -390.93 | 0.11386 | 4.9224 | -29.345 | |
| 3337 | -84.841 | 104.48 | 4.2766 | 1.6341 | |

MORE (YES, NO OR CONTINUOUS).

88888 POST1 ELEMENT STRESS LISTING 88888

| LOAD STEP | 1 | ITERATION | 1 | SECTION | 1 |
|-----------|-------------|-------------|---------|---------|---|
| TIME | 0.31000E-01 | LOAD CASE | 1 | | |
| ELEM | SDIR | SBZ | SBVI | SBZ2 | |
| 3342 | -153.98 | 56.975 | -5.7105 | 3.3457 | |
| 3343 | -327.00 | 0.73415E-02 | -57.418 | -28.807 | |
| 3344 | -81.580 | 5.2846 | -5.6923 | 2.7478 | |
| 3345 | -331.00 | 0.34046 | -123.81 | -103.81 | |
| 3346 | -611.00 | -0.11152 | -84.834 | -31.924 | |
| 3347 | -380.81 | 30.980 | -5.7041 | 7.1466 | |
| 3348 | -368.45 | 0.99504E-01 | 9.1267 | -41.220 | |
| 3349 | -119.91 | 104.84 | -4.0216 | 1.7616 | |

| | | | | |
|------|---------|---------|---------|---------|
| 3351 | 2335.1 | -448.71 | -83.841 | -317.02 |
| 3352 | -2134.8 | 358.79 | 168.80 | 223.13 |
| 3353 | -1149.7 | 924.09 | 39.435 | -7.6389 |
| 3354 | 1988.3 | -131.87 | -192.98 | -889.38 |
| 3355 | 2822.8 | -193.65 | -134.14 | -347.14 |
| 3356 | -2149.7 | 432.65 | 47.489 | 85.680 |

MORE (YES, NO OR CONTINUOUS).

88888 POST1 ELEMENT STRESS LISTING 88888

| LOAD STEP | 1 | ITERATION | 1 | SECTION | 1 |
|-----------|-------------|-----------|---------|---------|---|
| TIME | 0.31000E-01 | LOAD CASE | 1 | | |
| ELEM | SDIR | SBZ | SBVI | SBZ2 | |
| 3357 | -1107.0 | 385.47 | 120.63 | 68.725 | |
| 3358 | 1988.9 | -65.381 | -56.798 | -159.42 | |
| 3359 | -1141.2 | 939.87 | -38.669 | -10.825 | |
| 3361 | 1046.6 | -132.17 | 107.04 | -284.87 | |
| 3362 | -938.52 | 330.43 | -121.68 | 74.606 | |
| 3363 | 1941.4 | -77.082 | 26.898 | -169.14 | |
| 3364 | 2232.0 | -428.52 | 16.112 | -336.50 | |
| 3369 | -8000.3 | 358.18 | -172.18 | 238.31 | |
| 3379 | 2777.9 | -196.82 | 134.39 | -378.35 | |
| 3371 | -2098.9 | 478.72 | -45.091 | 78.136 | |
| 3372 | -2004.8 | 230.63 | 161.71 | -75.380 | |
| 3373 | 2392.2 | -41.134 | 129.84 | 100.44 | |
| 3374 | -3413.4 | -142.26 | 70.959 | -10.181 | |
| 3375 | 3630.0 | -214.55 | 47.884 | -107.38 | |

MORE (YES, NO OR CONTINUOUS).

88888 POST1 ELEMENT STRESS LISTING 88888

| LOAD STEP | 1 | ITERATION | 1 | SECTION | 1 |
|-----------|-------------|-----------|-------------|---------|---|
| TIME | 0.31000E-01 | LOAD CASE | 1 | | |
| ELEM | SDIR | SBZ | SBVI | SBZ2 | |
| 3376 | -3922.1 | 138.18 | 254.45 | -87.112 | |
| 3377 | 4442.7 | -104.96 | 73.470 | 396.71 | |
| 3378 | 3969.2 | 117.61 | -211.85 | 268.73 | |
| 3379 | -6860.5 | -205.53 | -66.388 | -449.45 | |
| 3380 | 3530.5 | -191.07 | -20.544 | -115.90 | |
| 3381 | -3510.9 | 142.57 | -215.67 | -61.367 | |
| 3382 | 4376.5 | -111.62 | -72.850 | 373.45 | |
| 3383 | -6812.7 | -273.38 | -48.102 | -475.45 | |
| 3384 | -1216.7 | 339.08 | -125.36 | -66.200 | |
| 3385 | 8639.4 | -29.164 | -70.978 | 167.53 | |
| 3386 | -3823.9 | -142.89 | -82.237 | -55.118 | |
| 3387 | 3542.4 | 82.210 | 69.907 | 216.30 | |
| 3388 | -4793.1 | 31709. | -364.76 | -16035. | |
| 3389 | 191.73 | 4934.2 | 0.00000E+00 | 10787. | |

MORE (YES, NO OR CONTINUOUS).

20000 POST1 ELEMENT STRESS LISTING 20000

LOAD STEP 1 ITERATION 1 SECTION 1

TIME 0.31000E-01 Load CASE 1

| ELEM | SDIR | SDZ | SDV1 | SDZ2 |
|------|---------|-------------|-------------|-------------|
| 3400 | -100.40 | 50.000 | 0.1027 | 3.0400 |
| 3471 | -100.70 | 1.2000 | 4.7014 | 2.7641 |
| 3472 | -317.00 | 0.3404 | 134.88 | -86.935 |
| 3474 | -370.04 | 0.82034 | 37.193 | -63.130 |
| 3494 | -826.06 | -3.4301 | -1.4031 | 0.23174 |
| 3506 | -1019.0 | -0.19937 | -228.45 | 31.000 |
| 3507 | -990.27 | 40.404 | 20.000 | 65.117 |
| 3508 | -1781.0 | 0.36166E-01 | 78.774 | 87.100 |
| 3509 | -1135.0 | 61.300 | -49.935 | 59.707 |
| 3510 | 83.704 | -14.728 | 300.55 | 93.651 |
| 3511 | 94.840 | 83.945 | 130.21 | 45.380 |
| 3512 | -812.20 | 18.407 | -11.959 | 118.72 |
| 3513 | -850.07 | 844.04 | 0.20007E-13 | 0.00000E+00 |
| 3515 | -10.027 | -4.0020 | 68.020 | -43.780 |

NOTE (YES,NO OR CONTINUOUS).

20000 POST1 ELEMENT STRESS LISTING 20000

LOAD STEP 1 ITERATION 1 SECTION 1

TIME 0.31000E-01 Load CASE 1

| ELEM | SDIR | SDZ | SDV1 | SDZ2 |
|------|---------|--------------|-------------|--------------|
| 3516 | -24.360 | -12.794 | 49.017 | -11.106 |
| 3523 | 5293.6 | -0.14511E+07 | 0.10404E+06 | 0.30528E+07 |
| 3524 | 4691.5 | 0.31056E+07 | 0.20705E+06 | 0.16080E+07 |
| 3525 | 4707.8 | -0.16080E+07 | 0.15501E+06 | 0.14511E+07 |
| 3526 | 4953.7 | 0.32007E+07 | 24814. | -0.18974E+07 |
| 3529 | 4865.4 | -0.18974E+07 | 18008. | -0.13050E+07 |
| 3530 | 5017.1 | -0.13050E+07 | -12932. | 0.28648E+07 |
| 3531 | 766.86 | 1.0000 | -2.2342 | -1.8168 |
| 3532 | -1307.0 | -8.0823 | -8.8761 | -0.18480E-02 |

POST1 -IMP.

PRINT REACTION FORCES PER NODE

***** POST1 REACTION FORCE LISTING *****
 LOAD STEP 1 ITERATION-1 SECTION-1
 TIME- 0.31000E-01 LOAD CASE-1
 THE FOLLOWING X,Y,Z FORCES ARE IN MODAL COORDINATES

| MODE | PX | PY | PZ | RX | RY |
|------|----|--------|----|----|----|
| 856 | | -918.5 | | | |
| 859 | | -8453. | | | |
| 863 | | -2043. | | | |
| 867 | | -1733. | | | |
| 868 | | -558.6 | | | |
| 869 | | -1166. | | | |
| 871 | | -835.0 | | | |
| 876 | | -64.43 | | | |
| 877 | | -52.18 | | | |
| 883 | | 15.88 | | | |
| 884 | | 513.0 | | | |
| 885 | | 60.01 | | | |

MORE (YES, NO OR CONTINUOUS)-

***** POST1 REACTION FORCE LISTING *****

LOAD STEP 1 ITERATION-1 SECTION-1
 TIME- 0.31000E-01 LOAD CASE-1
 THE FOLLOWING X,Y,Z FORCES ARE IN MODAL COORDINATES

| MODE | PX | PY | PZ | RX | RY |
|------|--------|--------|--------|----|----|
| 891 | | -36.56 | | | |
| 892 | | -67.77 | | | |
| 893 | | -831.1 | | | |
| 898 | | -1151. | | | |
| 900 | | -531.4 | | | |
| 901 | | -1707. | | | |
| 906 | | -884.0 | | | |
| 907 | | -2027. | | | |
| 911 | | -2454. | | | |
| 1278 | -704.8 | 273.5 | 470.8 | | |
| 1279 | -1108. | 426.2 | -188.6 | | |
| 1280 | -1484. | 308.3 | -161.1 | | |

***** POST1 REACTION FORCE LISTING *****

LOAD STEP 1 ITERATION-1 SECTION-1
 TIME- 0.31000E-01 LOAD CASE-1
 THE FOLLOWING X,Y,Z FORCES ARE IN MODAL COORDINATES

| MODE | PX | PY | PZ | RX | RY |
|------|--------|------------|--------|----|----|
| 1284 | -1352. | 3016. | -78.06 | | |
| 1285 | -868.0 | 1025. | -400.5 | | |
| 1288 | -1114. | 3601. | -977.3 | | |
| 1289 | -1757. | 1339. | -541.8 | | |
| 1290 | -1285. | 1154. | -464.8 | | |
| 1291 | -793.6 | 1946. | -773.1 | | |
| 1296 | 81.42 | 0.1039E+05 | -3286. | | |
| 1297 | -1186. | 2666. | -1074. | | |

1298 24.40 3847. -1082.
 1299 1888 9745. -8082.
 1304 271.5 0.1880E+05 -2045.
 1305 -1619. 8367. -3381.

***** POST1 REACTION FORCE LISTING *****
 LOAD STEP 1 ITERATION-1 SECTION-1
 TIME- 0.31000E-01 LOAD CASE-1
 THE FOLLOWING X,Y,Z FORCES ARE IN MODAL COORDINATES

| MODE | PX | PY | PZ | RX | RY |
|------|--------|-------|--------|----|----|
| 1306 | 183.4 | 6383. | -2474. | | |
| 1307 | 1051. | 6016. | -3202. | | |
| 1318 | 1320. | 3706. | -799.1 | | |
| 1313 | -1396. | 6351. | -2536. | | |
| 1314 | 326.3 | 3083. | -1804. | | |
| 1315 | 1479. | 8533. | -1080. | | |
| 1380 | 1414. | 3893. | -108.7 | | |
| 1381 | 989.4 | 1874. | -744.8 | | |
| 1382 | 1445. | 1116. | -447.8 | | |
| 1383 | 1829. | 1442. | -581.7 | | |
| 1388 | 1170. | 442.6 | -180.7 | | |
| 1389 | 818.8 | 1161. | -453.9 | | |

***** POST1 REACTION FORCE LISTING *****

LOAD STEP 1 ITERATION-1 SECTION-1
 TIME- 0.31000E-01 LOAD CASE-1
 THE FOLLOWING X,Y,Z FORCES ARE IN MODAL COORDINATES

| MODE | PX | PY | PZ | RX | RY |
|------|--------|--------|--------|----|----|
| 1332 | 737.4 | -115.1 | 386.0 | | |
| 1333 | 1441. | 234.7 | -85.57 | | |
| 1435 | -586.7 | | | | |
| 1440 | -187.6 | | | | |
| 2810 | | 1101. | | | |
| 2818 | | 1487. | | | |
| 2821 | | 1116. | | | |
| 2822 | | 1441. | | | |

TOTAL 1726. 0.9814E+05-0.3115E+05 0.0000E+00 0.0000E+00 0.00
 00E+00
 POST1 -IMP.

D3/160

CEL MEMO: DECEMBER 29, 1986 (PROGRESS)

FMC Central Engineering Laboratories
Santa Clara

Interoffice

To R. Rathe

From C. R. Ortloff

Subject **PROGRESS REPORT TO 28 DEC 86
AND RESULTS TO DATE SUMMARY**

Date Dec. 29, 1986

cc E. Thuse
A. Amberg
R. Kazares
E. Alexander
B. Anderson
J. Ries
L. Libhardt
B. Zierwick
P. Carroll

A brief summary of expenditures and progress to date is given to summarize CEL results on the LWHD Phase II project.

- o Of the \$1.4MM awarded to Northern Ordnance, \$60K is now scheduled for CEL Applied Mechanics and \$15K to MEL. Expenditures to date are: Applied Mechanics \$33K, MEL \$0K. Original budget of \$120K for Applied Mechanics was reduced to \$60K (10/86) with no reduction in expected work or schedule times. 2 m. item put
- o Design analysis and deliverables have been forwarded to Northern Ordnance for the most current available version of the cradle. Work to date includes a static analysis of the 27 layer foam core Gr/Ep sandwich structure under firing load maximums. Work performed by M. Rodamaker (ANSYS consultant) on the dynamic behavior of a simplified FE model of the cradle provided dynamic amplification factors between 1 to 1.5 used to modify the static results for an approximation to the dynamic stress state. The current cradle design apparently fails by a number of composite failure mechanisms (Memo: C. R. Ortloff to R. Rathe, 8 Dec 86) and is presently under redesign. Suggestions were forwarded with the above memo for a redesign of the filament wound structure with additional layers to produce a workable design. As yet, no response on the new design (woven roving layup) or acceptance of the suggested modified filament wound structure has been received for further analysis (as of 28 Dec 86). Hard copy of the static analysis was also forwarded (C. R. Ortloff to L. Libhardt, 16 Dec 86) as requested. 29 not sure
- o Dynamic analysis of the 0°-0° load case has been performed and results forwarded (Memo: CRO to L. Libhardt, 17 Dec 86). Analysis showed that the gimbal shaft attachment zones were overstressed and needed local reinforcement. The system appeared to be stable under dynamic firing loads.
- o Dynamic analysis of the 0°-72° load case has been performed and results forwarded (Memo: CRO to L. Libhardt, 28 Dec 86). Results indicate local failure of the gimbal upper and lower

arms in addition to local failure of the shaft attachment zones in the gimbal. These parts may be reinforced to meet strength requirements as outlined in the memo. In total, some 384 pages of computer hard copy output on stress results have been forwarded with these memos.

- o A description of the model, loads and boundary conditions (and accompanying hard copy) was sent (Memo: CRO to L. Libhardt, 22 Dec 86) by request in order to provide materials to NOD staff for ARDEC presentations. Further color transparencies were sent (Memo: CRO to L. Libhardt, 29 Dec 86) with additional descriptive material to add to the materials previously sent.
- o Estimates of the effects of thermal expansion and moisture absorption stresses were made (Memo: CRO to L. Libhardt, 22 Dec 86) for the cradle by the University of Delaware CMAP program.
- o The 22.50-720, 22.50-00 FE models are finished (3600 elements each). The 22.50-720 dynamic stress analysis case has been run and is currently in postprocessing. Each run is 32 CPU hours.
- o About \$30K work of CEL computer resources has been devoted to the project to date. Remaining load cases (LAPES loads, various soil models for the spade to react to, further design iterations, etc.) remain. It is estimated that several hundred CPU hours will be expended before the project is completed.
- o Investigations on thermal expansion stresses under hot, wet conditions for the cradle are underway (in the run queue). Further investigations of cradle buckling are being set up for a run in early January. Buckling effects may dominate survivability considerations for the cradle.
- o Considerable overtime (not charged to the project) has been devoted to accomplish the project's schedule and cost goals.
- o Numerous changes in FE models have been made throughout the history of the project. It is estimated that 10 major revisions and/or new models were made in the course of the project to keep up with the "current design" and provide stress results. Once the design was stabilized in December, stress reports ensued rapidly (5 reports in the month of December, for example). As of 28 Dec 86, no new design updates have been received for the trails or cradle. Once these are received, FE models will be revised quickly and rerun to test new design fixes.

R. Rathe
Progress Report to 28 Dec 86 and
Results to Date Summary

29 Dec. 86
Page 3

- o The computer loading for work to date has been high. Problems occurred with disk space available (450K blocks) compared to necessary disk space to run a problem (400K blocks). Use of M. Rodamaker's computer system alleviated the problem of running multiple problems simultaneously and permitted rapid progress to be made. It is recommended that 700K blocks be held in reserve for problems of this size and complexity. Fees for M. Rodamaker's work are to be taken out of the CEL budget at NOD's request.
- o In the spirit of cooperation, I ask for all current design updates to be sent to me as soon as possible so that I may modify the FE models and report results of the next design iteration. The more rapidly this process can occur, the more design iterations can be performed and the better the final design will be.
- o Four trips have been taken to NOD (CRO) and NOD personnel have visited CEL twice to discuss progress on the project. To date, no invitation to present FEA results or to visit ARDEC has been made to CEL to upgrade our understanding of latest developments on the project.


C. R. Ortloff

D3/170

CEL MEMO: DECEMBER 30, 1986

FMC Central Engineering Laboratories
Santa Clara

Interoffice

| | | | |
|---------|--|------|--|
| To | Larry Libhardt | Date | Dec. 30, 1986 |
| From | C. R. Ortloff | cc | E. Thuse A. Amberg R. Kazares J. Ries R. Rathe E. Alexander |
| Subject | RESPONSE TO REQUEST FOR COLOR GRAPHICS PLOTS FOR THE NOD/ARDEC PRESENTATION (9 FIGURES) IN JANUARY | | |

Enclosed are color transparencies showing the FEA model (0°-72° case) and various components of the full model. Also shown are some stress color fill plots representing the stress states at a given time during dynamic loading. I trust that these plots plus the several hundred B+W stress plots supplied with earlier memos will give you sufficient material to answer any questions at the design review meeting. Please contact me if you need any additional presentation or descriptive material before your meeting.

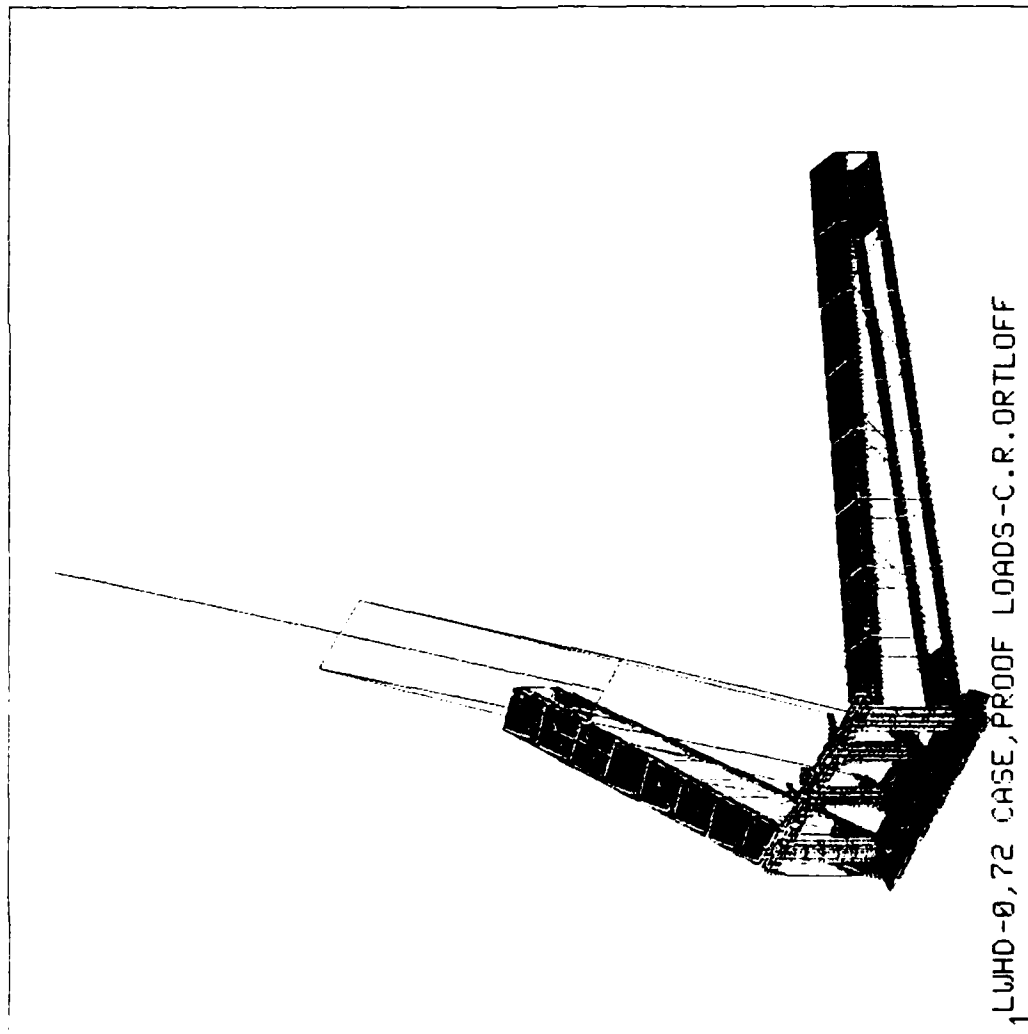
Please store all original hard copy material in a cool, dry place (or xerox as required) as these originals will darken with exposure to light. At some later time, I may request some of these originals to be returned for inclusion in the final stress report.

C. R. Ortloff

C. R. Ortloff

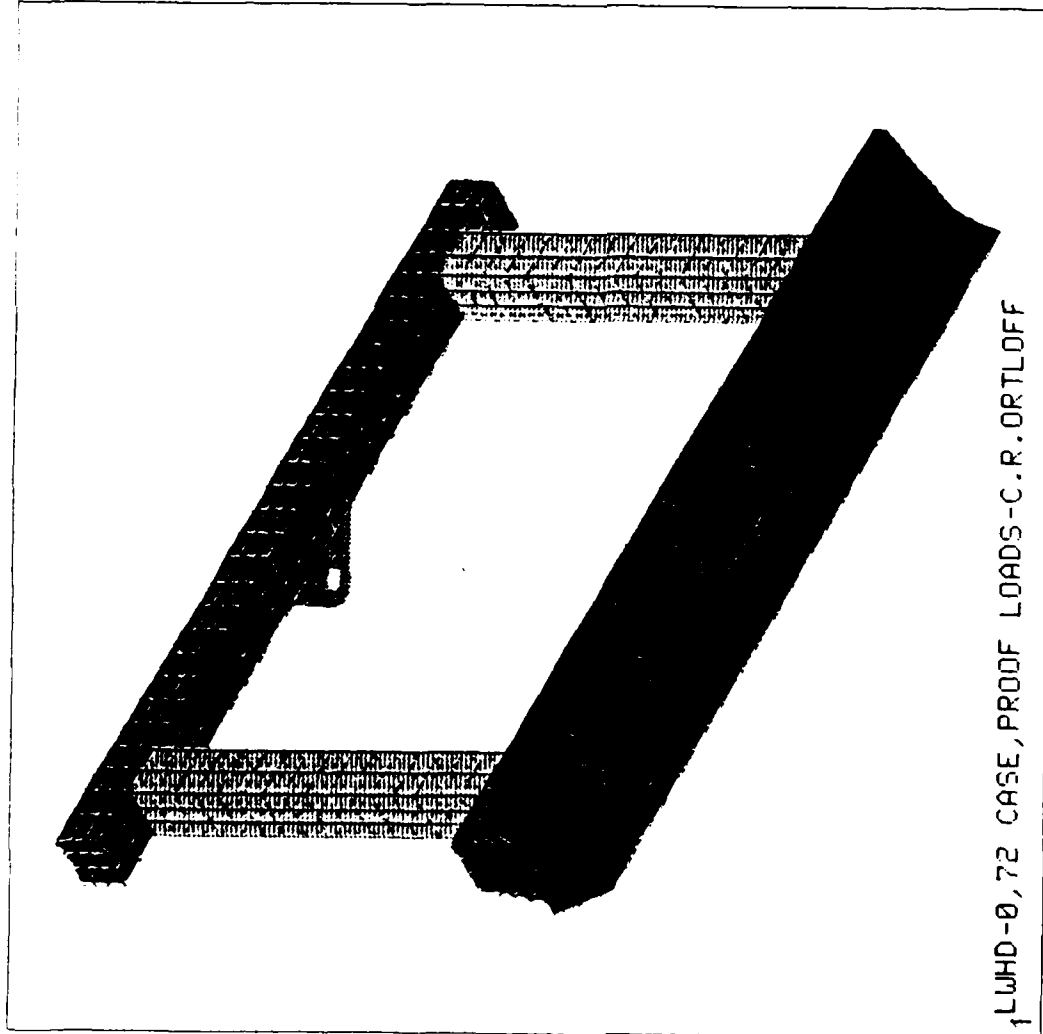
ANSYS 4.28
DEC 29 1986
16:30:56
PREP7 ELEMENTS
RNUM=1

XU=1
YU=1
ZU=1
* DIST=229
* XF=43.2
* YF=127
* ZF=-172
HIDDEN



ANSYS 4.28
DEC 29 1986
15:00:56
PREP7 ELEMENTS
RNUM=1

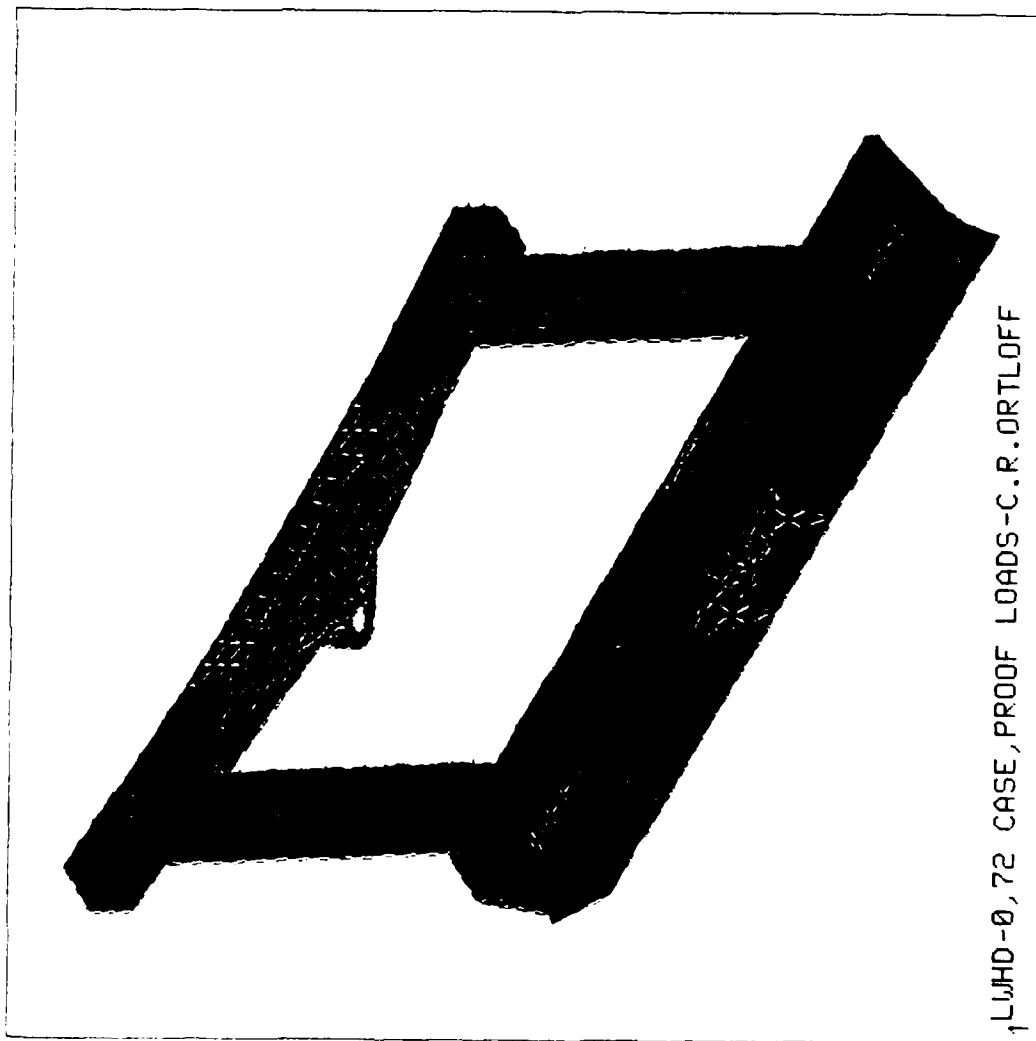
XU=-1
YU=-1
ZU=1
* DIST=58.2
* XF=54.2
* YF=26.4
* ZF=4.85
HIDDEN



1LWHD-0,72 CASE,PROOF LOADS-C.R.ORTLOFF

ANSYS 4.28
 DEC 29 1986
 13:59:00
 PDST1 STRESS
 STEP=1
 ITER=1
 TIME=.031
 SIGE
 TDP

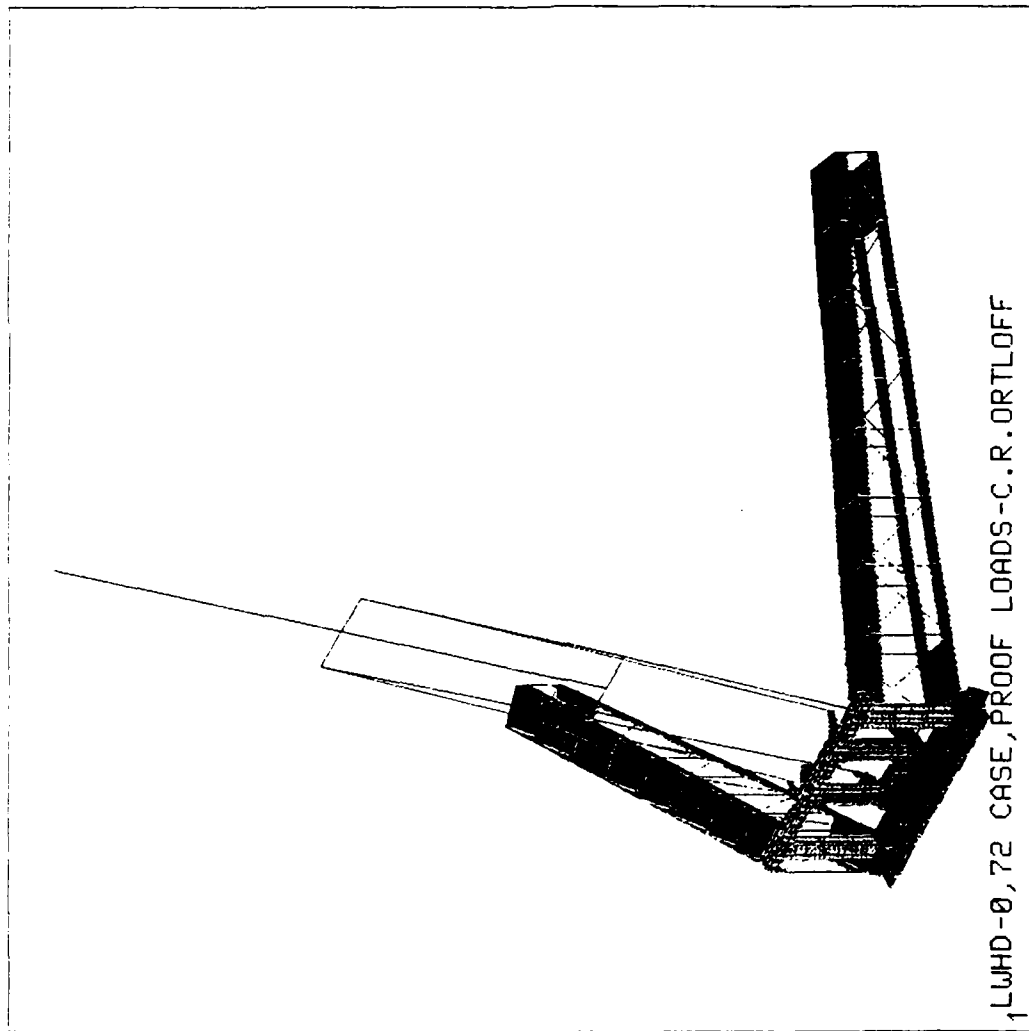
XU=-1
 YU=-1
 ZU=1
 DIST=58.2
 XF=54.2
 YF=26.4
 ZF=4.85
 HIDDEN
 MX=52416
 MN=345
 6854
 13363
 19372
 26331
 32390
 39399
 45988
 52417



1LWHD-0,72 CASE, PROOF LOADS-C.R.ORTLOFF

ANSYS 4.2B
DEC 29 1986
16:30:56
PREP7 ELEMENTS
RNUM=1

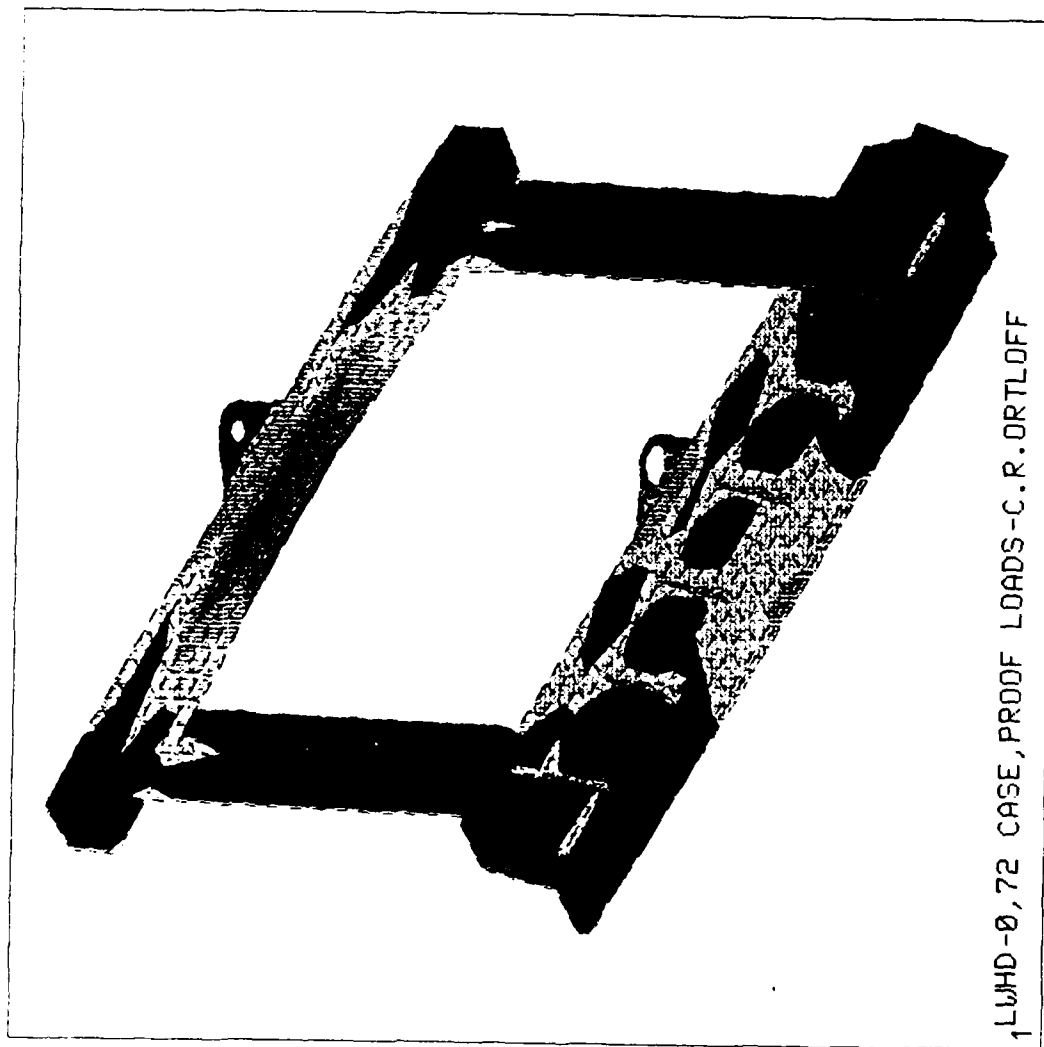
XU=1
YU=1
ZU=1
* DIST=229
* XF=43.2
* YF=127
* ZF=-172
HIDDEN



ANSYS 4.2B
 DEC 29 1986
 14:18:24
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.031
 SIGE
 TOP

XU=1
 YU=1
 ZU=1
 DIST=56.6
 XF=51.2
 YF=27.7
 ZF=4.17
 HIDDEN
 MX=52416
 MN=345
 6854

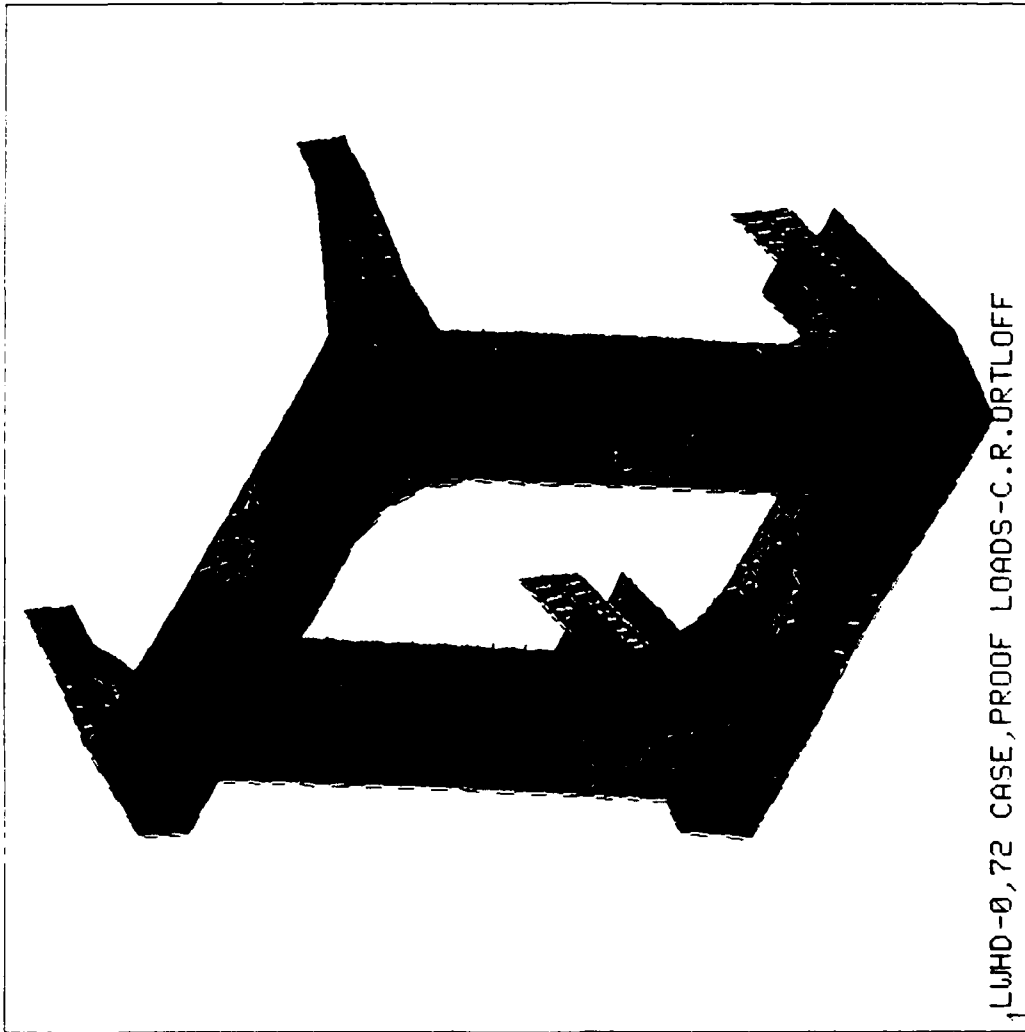
10000
 26331
 32390
 39399
 45908
 52417



1 LUHD-0,72 CASE,PROOF LOADS-C.R.ORTLOFF

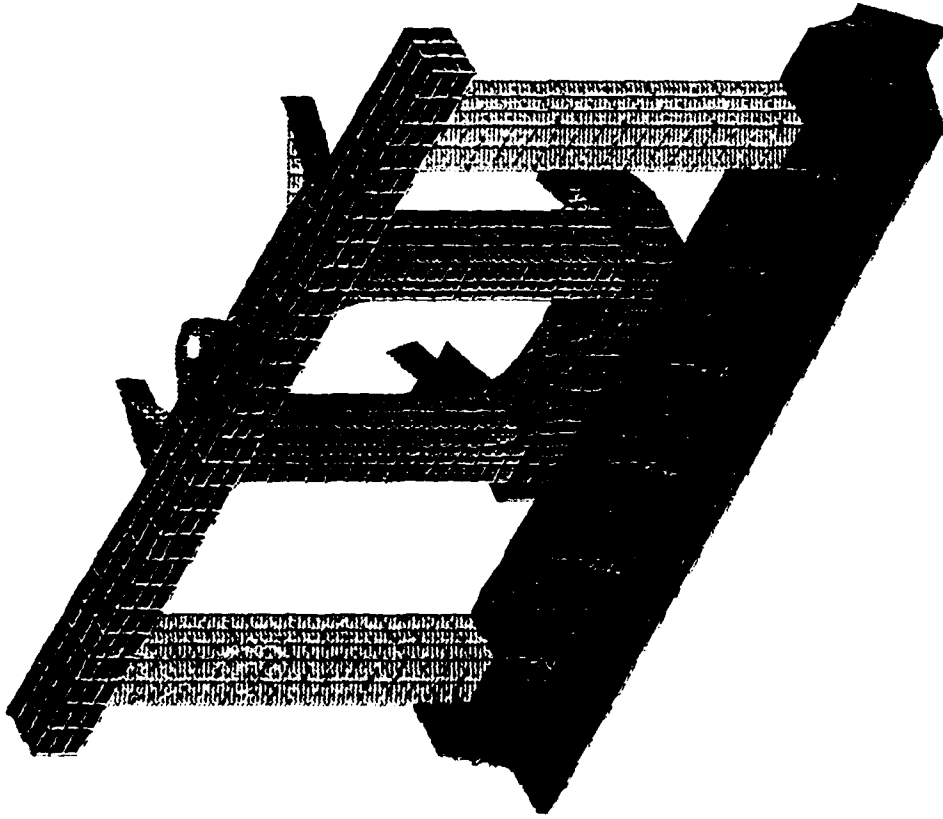
ANSYS 4.2B
DEC 29 1986
13:46:25
POST1 STRESS
STEP=1
ITER=1
TIME=.031
SIGE
TOP

XU=1
YU=1
ZU=1
DIST=34.2
XF=54.9
YF=33.9
ZF=-8.01
HIDDEN
MX=155611
MN=2472
21613
40756
59399
79042
98185
117323
131451
155614



ANSYS 4.2B
DEC 29 1986
15:56:30
PREP7 ELEMENTS
RNUM=1

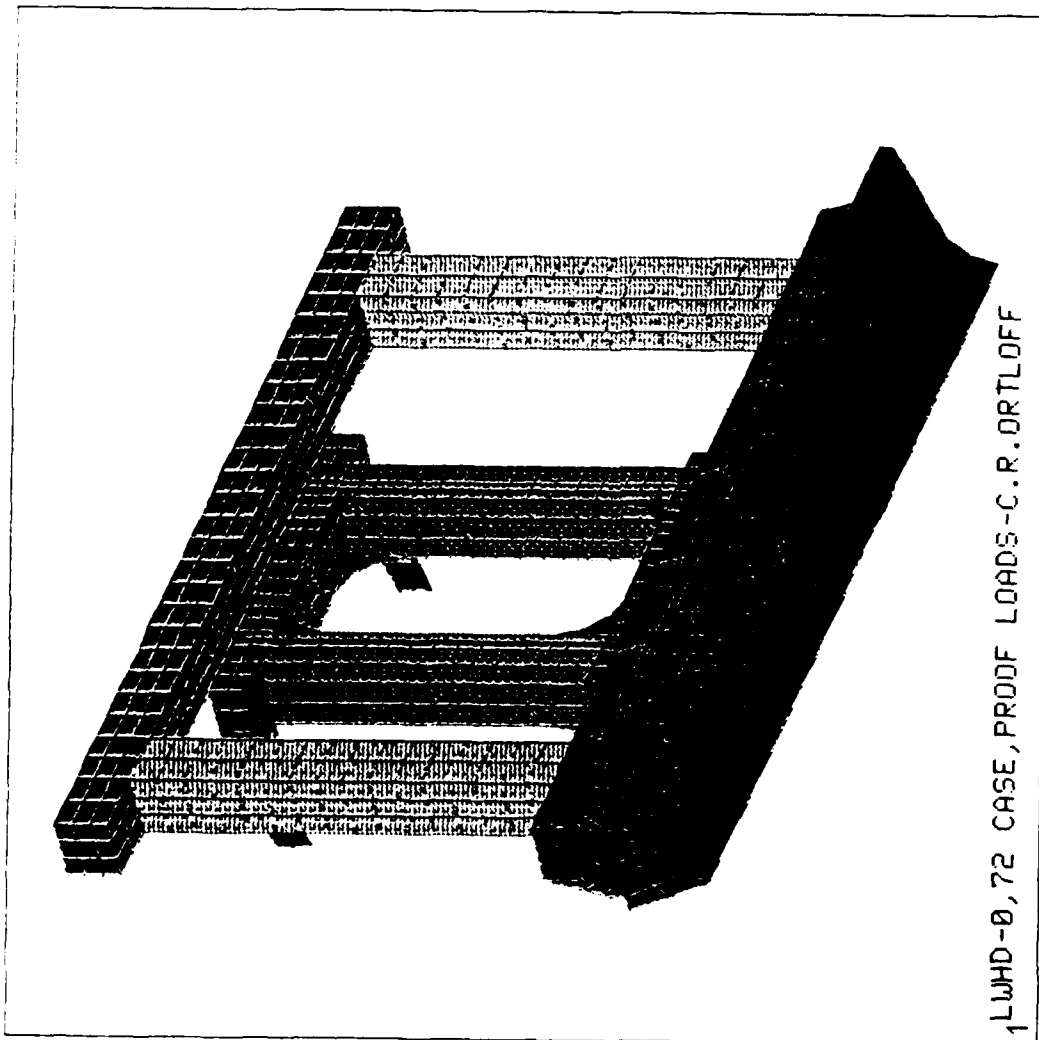
XU=1
YU=1
ZU=1
DIST=56.6
XF=51.2
YF=27.7
ZF=4.17
HIDDEN



1,LUHD-0,72 CASE,PROOF LOADS-C.R.ORTLOFF

ANSYS 4.2B
DEC 29 1986
15:35:57
PREP7 ELEMENTS
RNUM=1

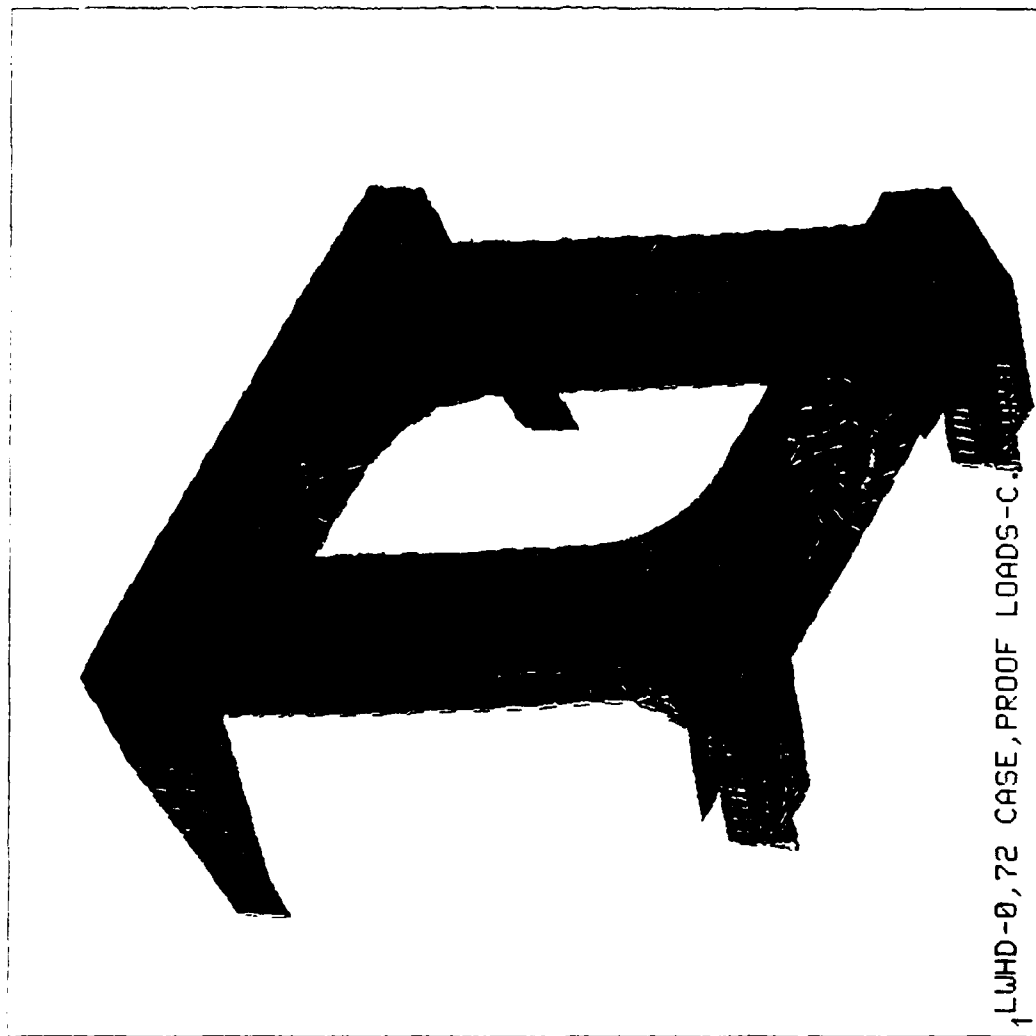
XU=-1
YU=-.5
ZU=.8
DIST=54.8
XF=53.4
YF=26.1
ZF=5.66
HIDDEN



1,LUHD-0,72 CASE,PRODF LOADS-C.R.ORTLOFF

ANSYS 4.2B
DEC 29 1986
13:26:32
POST1 STRESS
STEP=1
ITER=1
TIME=.031
SIGE
TOP

XU=-1
YU=-1
ZU=1
DIST=32.7
XF=51.6
YF=35.2
ZF=-8.57
HIDDEN
MX=155611
MN=2472
21613
40756
59899
79042
93185
117328
155614



ANSYS 4.28
DEC 29 1986
14:40:21
POST1 STRESS
STEP=1
ITER=1
TIME=.031
SIGE
TOP

ZOOM
XU=1
YU=1
ZU=1
* DIST=7.31
* XF=62.4
* YF=13.3
* ZF=8.63
XRTD=1.16
HIDDEN
MX=45606
MN=695
5682
10673
15664
20655
30637
35628
40619
45610

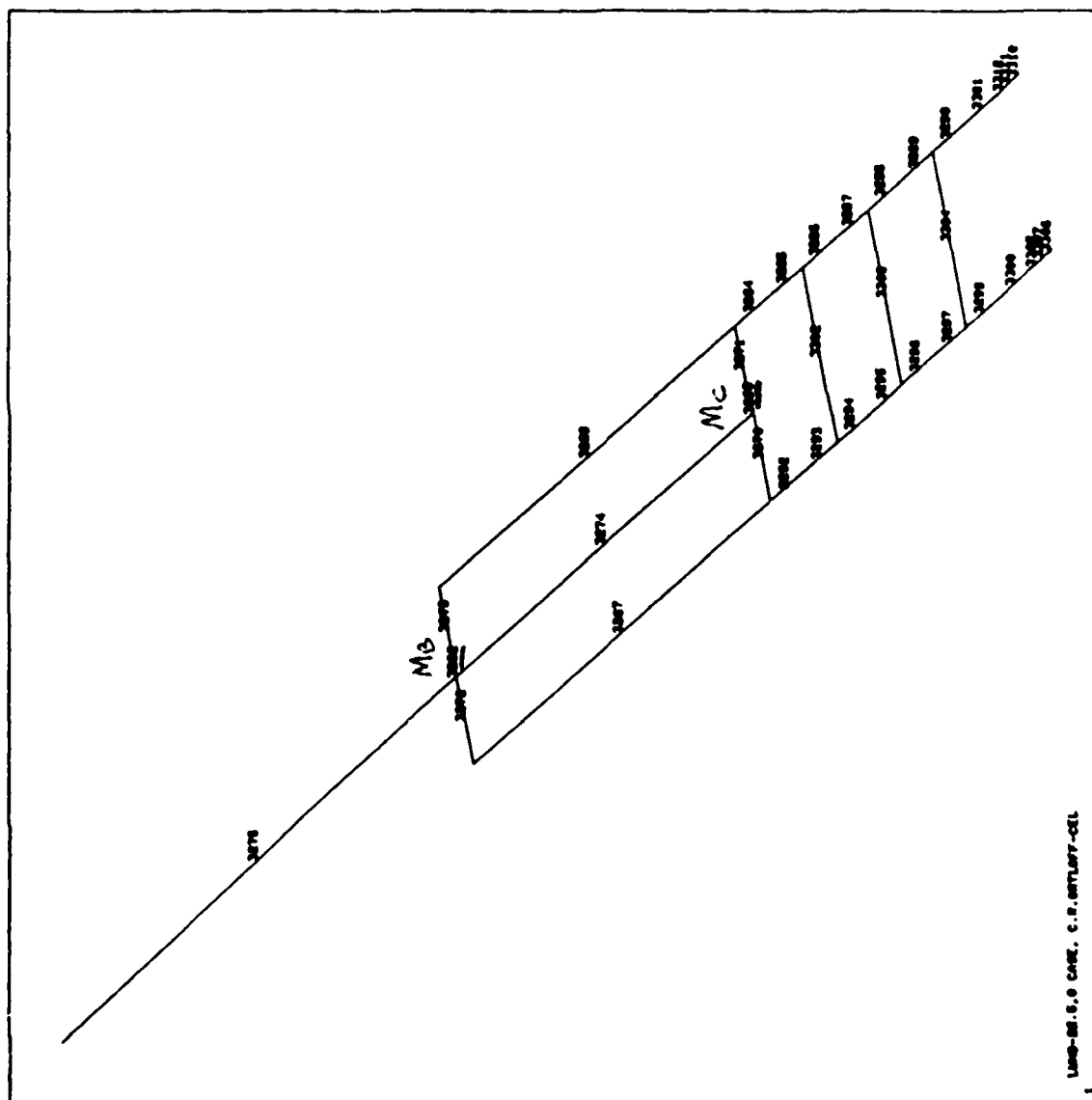


1LWHD-0,72 CASE,PROOF LOADS-C.R.ORTLOFF

CONCENTRATED MASSES

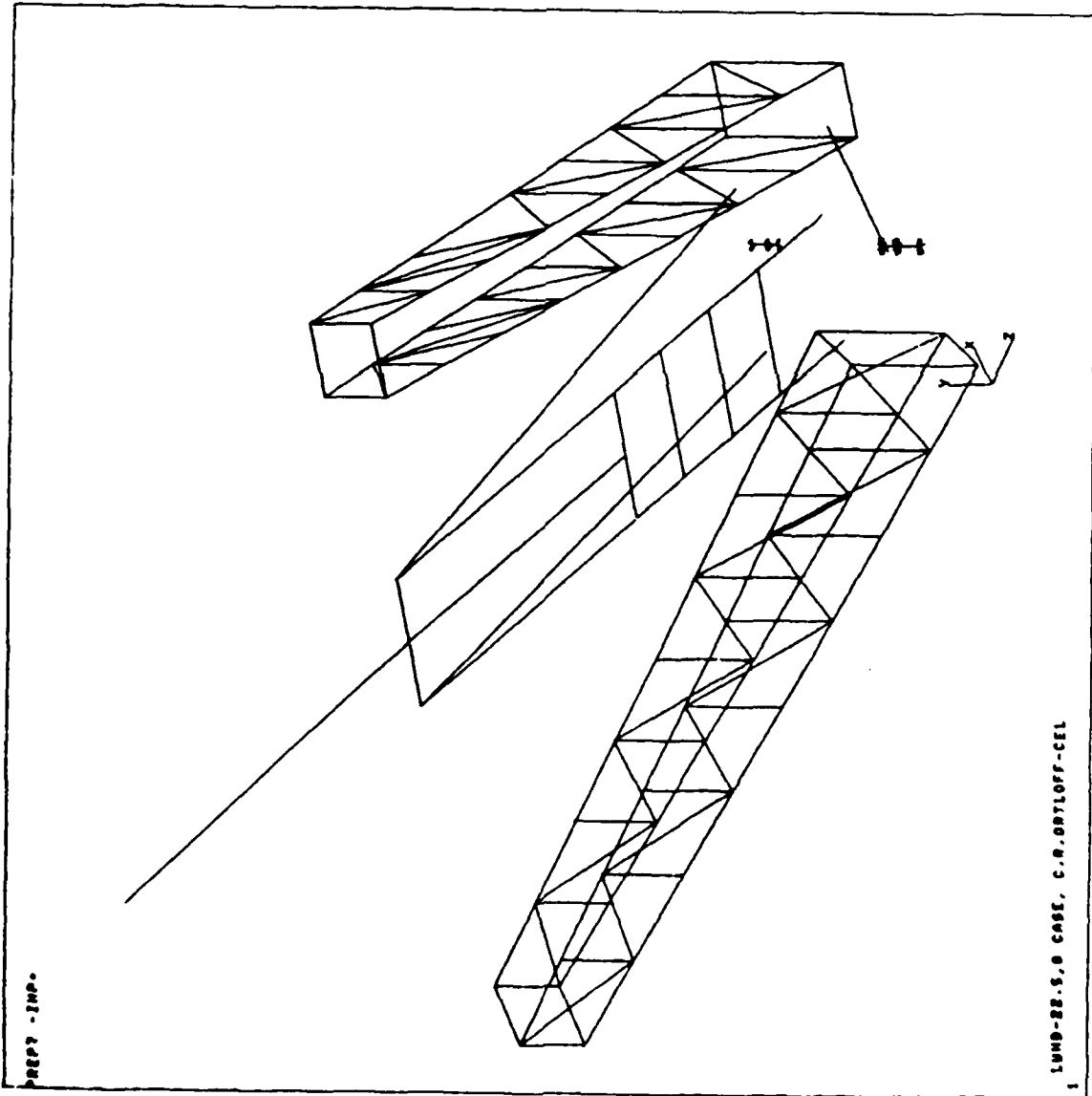
40000 4.00
200 5.0007
14100120
PROPERTY ELEMENTS
DASH-1

- 0107-121
- 107-141
- 107-18.2
- 107-183
- 1070-1.04



ANSYS 4.20
JAN 7 1987
13167133
PREP7 ELEMENTS

ZOOM
XU=-1
VU=1
ZU=1
DIST=167
XP=114
VP=81.5
ZF=-174
KSTO=1.24



PREP7 -IMP.

1, LUND-22.S.O CASE, C.R.ORTLOFF-CEL

STF 4
BEAM ELEMENTS

D3/180

CEL MEMO: JANUARY 7, 1987

FMC Central Engineering Laboratories
Santa Clara

Interoffice

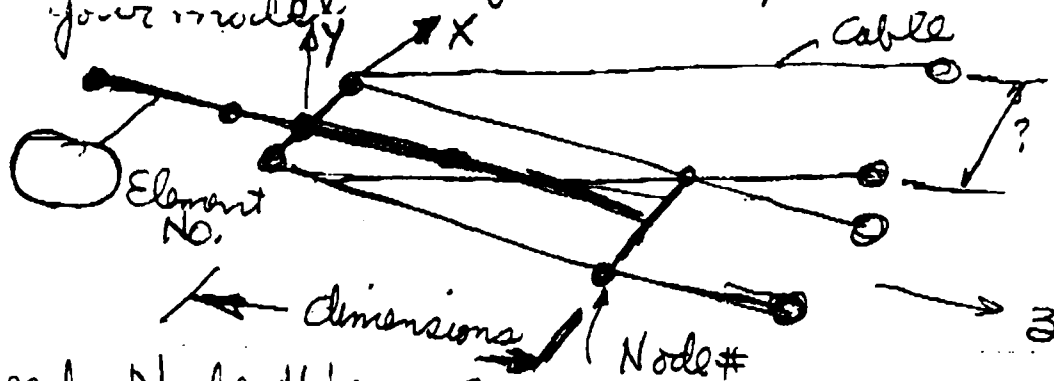
| | | | |
|---------|--------------------------------|------|---|
| To | L. Libhardt | Date | January 7, 1987 |
| From | C. R. Ortloff | cc | R. Rathe R. Kazares J. Ries E. Thuse |
| Subject | DELIVERY OF REQUESTED MATERIAL | | |

Pursuant to our 7 January 87 telecall, I am forwarding three requested items immediately. I will forward additional color transparencies tomorrow as requested. The 22.5°-0° system load case is done and a memo will be forwarded to you before 9 January 87.


C. R. Ortloff

1/7/87

We need a sketch of the finite element representation of the Gun/Cradle used in your model.



Need Node #'s

Need Weights / Masses & rotary Inertias

Need Dimensions

Element #'s & types of elements

Beam Properties for gun, cradle, cables

E values

A.

LWHD

BOUNDARY CONDITIONS

HARD SOIL EMPLACEMENT

- FIXED LOWER EDGE OF SPADE ($U_X = U_Y = U_Z = 0$)
- CONSTRAINTS ON VERTICAL DISPLACEMENT OF THE HORIZONTAL PLATE PART OF THE SPADE ($U_Y = 0$ AT SELECTED NODES ON THE PLATE)
- FREE TRAIL ENDS

SOFT SOIL EMPLACEMENT

- "EQUIVALENT" SPRING (MATCHING SOIL ELASTICITY) ATTACHED BETWEEN SPADE AND GROUND IN HORIZONTAL, VERTICAL DIRECTIONS
- FREE TRAIL ENDS

B.

LUMPED MASSED

- MASS OF BARREL, CRADLE INPUT AS LUMPED MASS IN TOTAL SYSTEM FINITE ELEMENT MODEL
- ALL OTHER MASS INPUT AS DISTRIBUTED MASS (I.E., DENSITY PRESCRIBED FOR ALL MATERIALS USED

| | | |
|--------------|---|-----|
| AD-A183 993 | LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR PHASE 1 AND PARTIAL PHASE 2 VOLUM (U) FMC CORP MINNEAPOLIS MINN NORTHERN ORDNANCE DIV R RATHJE ET AL APR 87 | 4/5 |
| UNCLASSIFIED | FMC-E-3041-VOL-D3-PT-1 DAAA21-86-C-0047 F/G 19/6 | NL |

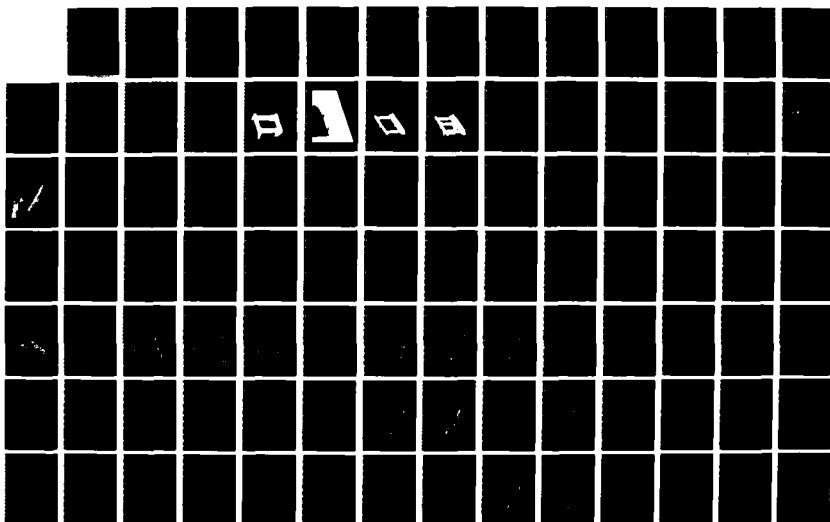
LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR PHASE 1 AND
 PARTIAL PHASE 2 VOLUM (U) FNC CORP MINNEAPOLIS MINN
 NORTHERN ORDNANCE DIV R RATHE ET AL APR 87
 FNC-E-3041-VOL-D3-PT-1 DAAA21-86-C-0047 E/G 19/6

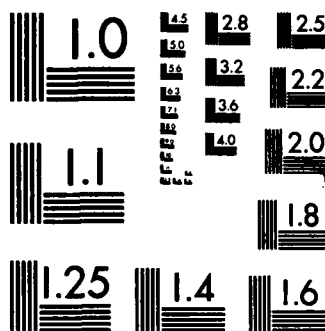
4/5

UNCLASSIFIED

F/G 19/6

NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

c. WHAT/WHAT NOT CONSIDERED (WHAT)

- 3600 ELEMENT FE MODEL
- CRADLE FREE TO ROTATE ON GIMBAL BEARINGS (ROTX NOT FIXED IN LOCAL COORDINATE SYSTEM)
- CABLES HAVE LOW EI TO PREVENT COMPRESSIVE STIFFNESS AND CORRECT E TO ALLOW FOR TENSIONAL EXTENSION
- ALL MASS REPRESENTED AS EITHER CONCENTRATED OR DISTRIBUTED MASS
- GRAVITY LOADS CONTINUOUSLY APPLIED
- GIMBAL IF FREE TO ROTATE WITHIN PLATFORM (ATTACHMENT SHAFTS HAVE ZERO TORSIONAL RESISTANCE BUT HAVE BENDING STIFFNESS)
- A LIMITER BEAM BETWEEN GIMBAL AND PLATFORM LIMITS GIMBAL ROTATION
- CRADLE MODEL (IN SYSTEM FE MODEL) REPRESENTED BY A BEAM ELEMENT FRAME APPROXIMATING BENDING AND TORSIONAL RESISTANCE OF CRADLE
- LINEAR TRANSIENT DYNAMIC LOADING OF THE SYSTEM MODEL
- FORCES AT TRAIL/PLATFORM CONNECTIONS
- ROTARY MOMENT OF INERTIA OF CRADLE REPRESENTED

C. WHAT/WHAT NOT CONSIDERED
(WHAT NOT)

- NONLINEAR EFFECTS OF THE SOIL MODEL / SPADE INTERACTION UNDER FIRING LOADS
- CABLE NONLINEARITIES (LARGE DEFLECTION, BILINEAR BEHAVIOR)
- FULL FE MODEL FOR CRADLE (29 LAYER G R / EP FOAM CORE STRUCTURE) APPENDED TO SYSTEM MODEL (ONLY A REPRESENTATIVE BEAM ELEMENT MODEL OF THE CRADLE USED)
- STATIONARY BARREL POSITION DURING FIRING

◦

D. MANNER OF LOADING

- FORCE vs. TIME DYNAMIC LOADING CURVES FOR RECOIL AND TORQUE FORCES INPUT INTO ANSYS LINEAR TRANSIENT DYNAMIC ANALYSIS (BY /PREP6 ROUTINES (PROOF LOAD LEVELS))
- TIME STEP: 0.001 SEC
LOADS ~~BY~~ RAMPED BETWEEN TIME STEPS
TIME OF ANALYSIS 0 TO 1 SECOND
- 1 G GRAVITY LOAD CONTINUOUSLY APPLIED DURING LOADING

E.

WORST ENVIRONMENT

- HOT, WET CONDITIONS FOR COMPOSITE CRADLE (1-2% MOISTURE, 150°F)
- HARD GROUND EMPLACEMENT
- PROOF LOAD DYNAMIC FORCE-TIME HISTORIES AS INPUT LOADS
- FREE TRAIL ENDS

F. STRESS REDUCTION IMPROVEMENTS PLAN

EXAMINATION OF STRESS RESULTS FOR THE 0°-0°, 0°-72°, 30°-50° CASES INDICATES THE FOLLOWING CHANGES TO BE MADE TO THE TOTAL SYSTEM STRUCTURE

- REINFORCE GIMBAL/CRADLE MOUNT ARMS (UPPER AND LOWER)
- REINFORCE (LOCALLY) THE GIMBAL SHAFT ZONES IN BOTH UPPER AND LOWER BOX BEAMS
- REDUCE THICKNESS OF THE PLATFORM AND GIMBAL VERTICAL BOX BEAMS (WEIGHT SAVING)
- REINFORCE TRIANGULAR ELEMENTS BETWEEN LOWER PLATFORM BOX BEAM AND SPADE HORIZONTAL PLATE IN CENTER SECTION
- THICKEN THE REAR PLATE OF THE UPPER GIMBAL AND PLATFORM BOX BEAMS

| LIST SELECTED MODES IN THE RANGE 2087 TO 2097 BY 1 DVS. | | | | | |
|---|---------|--------|---------|------|------|
| MODE | X | Y | Z | TWV | TWZ |
| 2087 | -815.00 | 10.175 | -400.00 | 0.00 | 0.00 |
| PHOT-IMP. | | | | | |
| 2092 | | | | | |

| MODE | X | Y | Z | THW | THV | THZ |
|------|--------|--------|---------|------|------|------|
| 2002 | 137.17 | 10.175 | -251.14 | 0.00 | 0.00 | 0.00 |
| DEPT | -144. | | | | | |
| 3000 | | | | | | |

| MODE | X | Y | Z | THW | THVZ | THWZ |
|------|--------|--------|---------|------|------|------|
| 3000 | 45.006 | 18.175 | -28.543 | 0.00 | 0.00 | 0.00 |
| DEP | -IMP. | | | | | |
| 3006 | | | | | | |

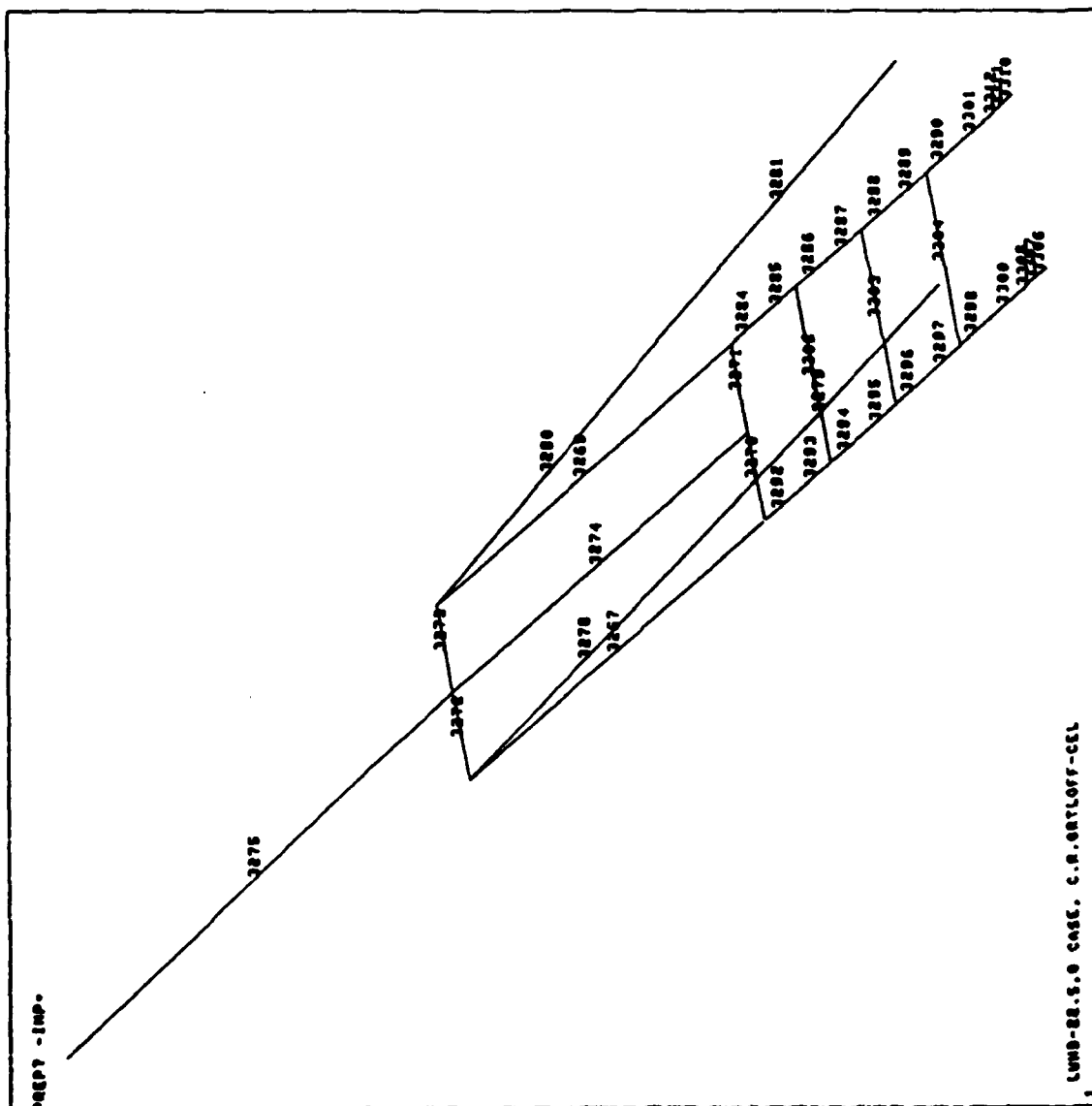
| MODE | X | Y | Z | THXV | THVZ | THXZ |
|------|--------|--------|---------|------|------|------|
| 3006 | 76.508 | 18.176 | -15.831 | 0.00 | 0.00 | 0.00 |
| DEPT | -IMP. | | | | | |
| 2043 | | | | | | |

| MODE | X | Y | Z | TMXV | TMXZ | TMXZ |
|------|--------|--------|---------|------|------|------|
| 2863 | 90.485 | 18.175 | -138.43 | 0.00 | 0.00 | 0.00 |
| 2867 | -IMP. | | | | | |
| 2779 | | | | | | |

| LIST SELECTED MODES IN THE RANGE 2770 TO 2770 BY 1 DEVS. 0 | | | | |
|--|--------|--------|---------|------|
| MODE | X | Y | Z | |
| 2770 | 30.142 | 51.775 | -27.833 | THVZ |
| 2767 -IMP. | | | | 0.00 |
| | | | | THVZ |
| | | | | 0.00 |

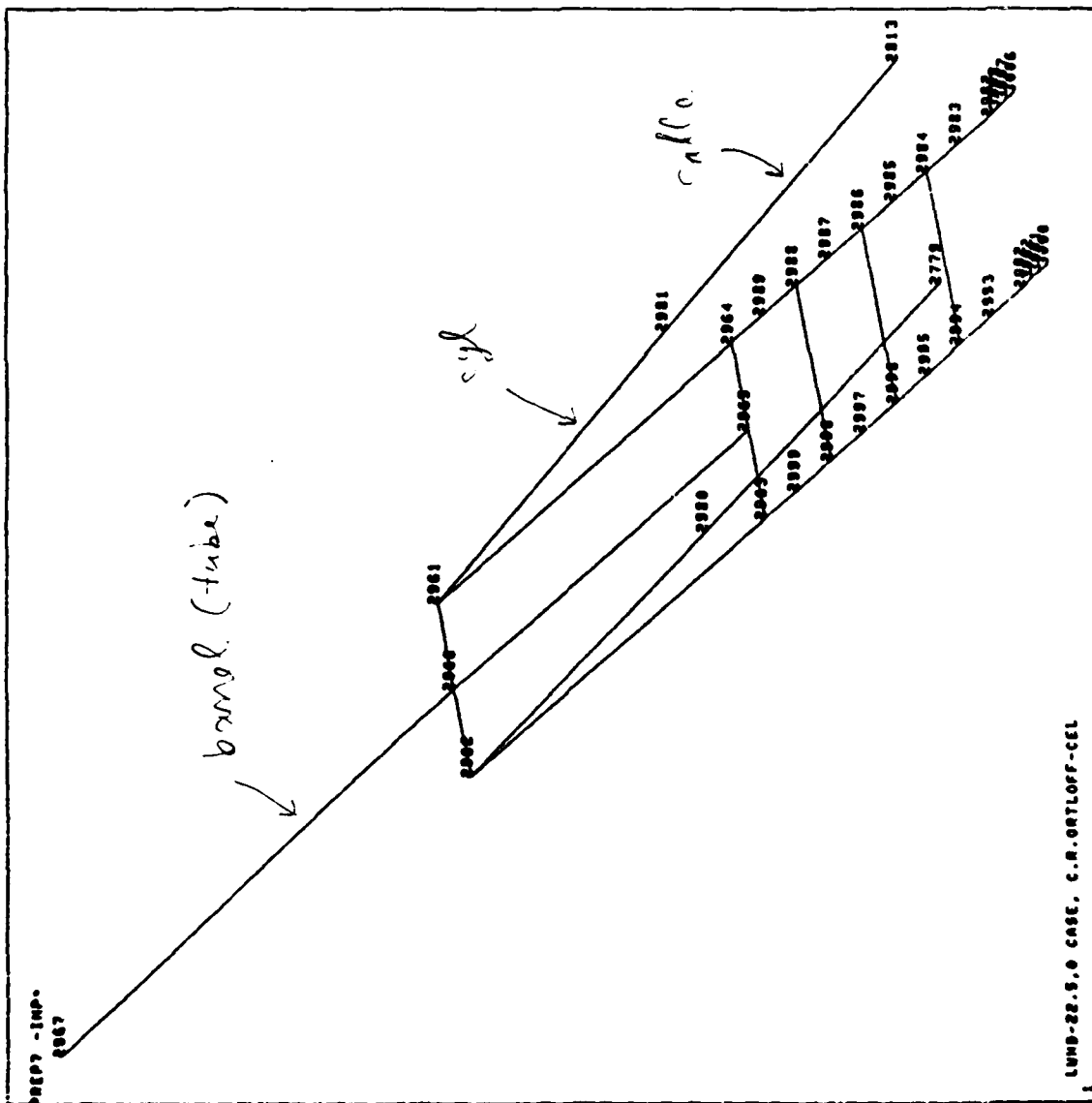
KEY NODE POSITIONS

ANSYS 4.20
 JAN 7 1987
 13145116
 PREP7 ELEMENTS
 CHUN-1
 ZOOM
 KU--1
 VU--1
 ZU--1
 0187-123
 KF-136
 VF-25
 ZF--104
 XRT0-1.24



ELEMENTS

ANSYS 4.20
 JAN 7 1987
 13144152
 PREP7 ELEMENTS
 MNUM=1
 ZOOM
 XU=-1
 VU=1
 ZU=1
 DIST=123
 XF=136
 YF=26
 ZF=-194
 XRT0=1.24



nodes

ELIST,3000

LIST SELECTED ELEM. IN RANGE 3000 TO 3000 BY 1 (LIST NODES)

ELER MAT TYP REL NODES

3000 27 6 27 2004 2001 0

PREP7 -IMP.
.3000

LIST SELECTED ELEM. IN RANGE 3000 TO 3000 BY 1 (LIST NODES)

ELER MAT TYP REL NODES

3000 27 6 27 2005 2004 0

PREP7 -IMP.
MPLIST,27

LIST MATERIALS 27 TO 27 BY 1

PROPERTY. ALL

PROPERTY TABLE EX MAT= 27 NUM. POINTS= 2
TEMPERATURE DATA TEMPERATURE DATA
0.00000E+00 0.30000E+08 2300.0 0.30000E+08

PROPERTY TABLE MUZY MAT= 27 NUM. POINTS= 2
TEMPERATURE DATA TEMPERATURE DATA
0.00000E+00 0.30000 2300.0 0.30000

PROPERTY TABLE BEMS MAT= 27 NUM. POINTS= 2
TEMPERATURE DATA TEMPERATURE DATA
0.00000E+00 0.50000E-07 2300.0 0.50000E-07

PREP7 -IMP.
ELIST,27

LIST REAL SETS 27 TO 27 BY 1

REAL CONSTANT SET 27 ITEMS 1 TO 6 4.0000 4.0000 0.00000E+00
10.000 500.00 500.00
PREP7 -IMP.

CRADLE
ELEMENTS
NOTE LARGE EI,
ie, FRAME IS
VERY STIFF. MASS
OF CRADLE IS ADDED
BY STIF 21 ELEMENT

LIST SELECTED ELEM. IN RANGE 3201 TO 3201 BY 1 (LIST MODES)

ELEM MAT TYP DEL MODES

3201 20 3 20 2001 2013 0
PROPERTY -IMP.
MPLIST,20

LIST MATERIALS 20 TO 20 BY 1
PROPERTY: ALL

PROPERTY TABLE EX MAT. 20 NUM. POINTS. 2
TEMPERATURE DATA TEMPERATURE DATA
0.00000E+00 0.12000E+00 2300.0 0.12000E+00

PROPERTY TABLE EV MAT. 20 NUM. POINTS. 2
TEMPERATURE DATA TEMPERATURE DATA
0.00000E+00 0.12000E+00 2300.0 0.12000E+00

PROPERTY TABLE MUZY MAT. 20 NUM. POINTS. 2
TEMPERATURE DATA TEMPERATURE DATA
0.00000E+00 0.30000 2300.0 0.30000

PROPERTY TABLE DENS MAT. 20 NUM. POINTS. 2
TEMPERATURE DATA TEMPERATURE DATA
0.00000E+00 0.10780E-03 2300.0 0.10780E-03

PROPERTY -IMP.
MPLIST,20

LIST REAL SETS 20 TO 20 BY 1

REAL CONSTANT SET 20 ITEMS 1 TO 6
2.0000 0.10000E-05 0.10000E-05 1.0000
PROPERTY -IMP.

1.0000 0.00000E+00

A IXX IYY TH1 TH2

CABLE

(NOTE THAT IXX, IYY
ARE SMALL SO THAT
EI IS SMALL (SMALL
E I IS SMALL (SMALL

ELIST.278

LIST SELECTED ELEMS. IN RANGE 3875 TO 3876 BY 1 (LIST MODES)

ELEM MAT TYP REL MODES

3875 27 0 27 2887 2888 0
PREPT -IMP.
MPLIST.27

LIST MATERIALS 27 TO 27 BY 1
PROPERTY. ALL

PROPERTY TABLE IN MAT. 27 NUM. POINTS. 2
TEMPERATURE DATA TEMPERATURE DATA
0.00000E+00 0.30000E+08 2300.0 0.30000E+08

PROPERTY TABLE NUMV MAT. 27 NUM. POINTS. 2
TEMPERATURE DATA TEMPERATURE DATA
0.00000E+00 0.30000 2300.0 0.30000

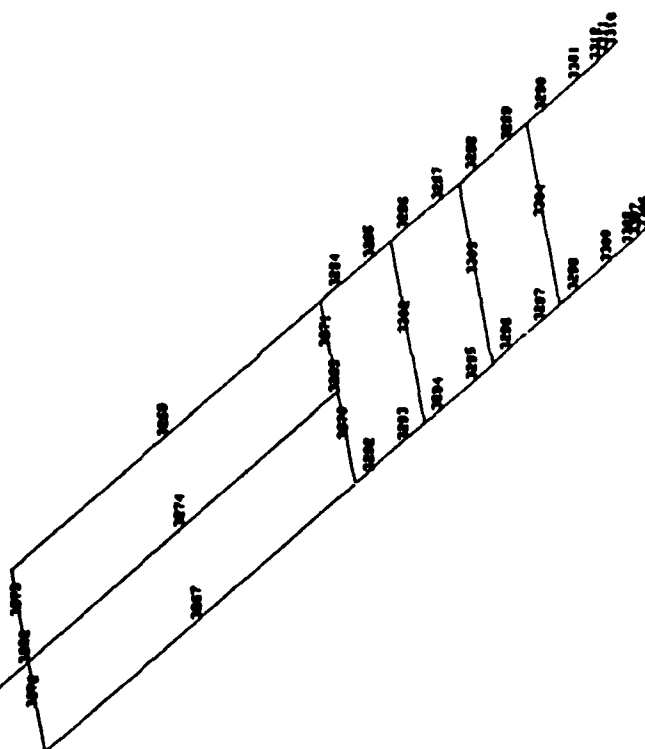
PROPERTY TABLE DENS MAT. 27 NUM. POINTS. 2
TEMPERATURE DATA TEMPERATURE DATA
0.00000E+00 0.00000E-07 2300.0 0.00000E-07

PREPT -IMP.
MPLIST.27

LIST REAL SETS 27 TO 27 BY 1

REAL CONSTANT SET 27 ITEMS 1 TO 6 4.0000 4.0000 0.00000E+00
10.000 500.00
PREPT -IMP.

BARREL
PROPERTIES
(NOTE BARREL
MASS IS ADDED
AS A CONCENTRATED



RL187,30,30.1

LIST REAL SETS 30 TO 39 BY 1

REAL CONSTANT SET 30 ITEMS 1 TO 6

8.0000 8.0000 0.00000E+00 0.00000E+00 002.00

REAL CONSTANT SET 30 ITEMS 1 TO 6

7.0000 7.0000 0.00000E+00 0.00000E+00 10.000

ROTARY, Z-AXIS

MASS ACTS IN X, Y, Z DIRECTIONS SIMULTANEOUSLY

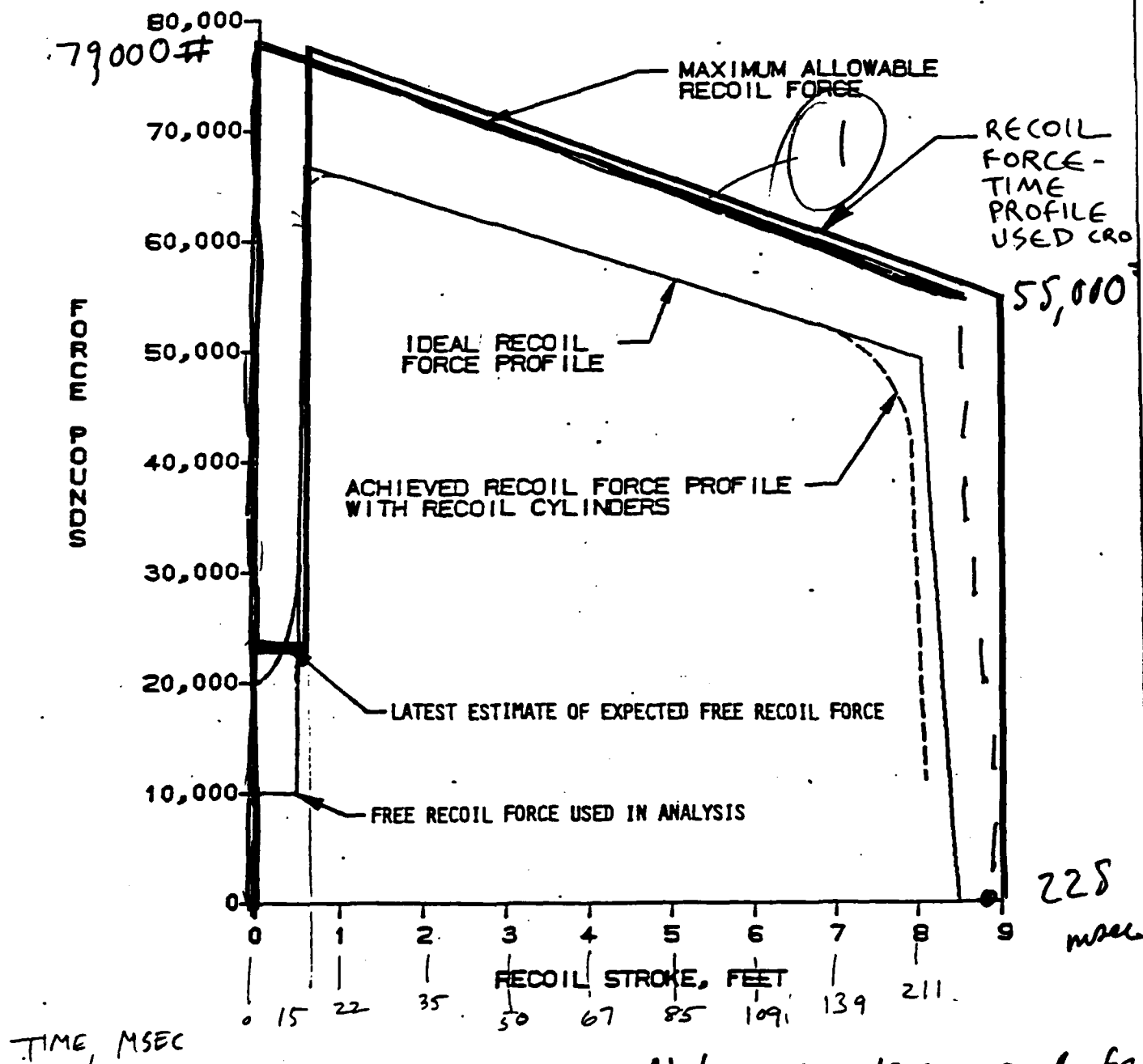
MULTIPLY ABOVE VALUES
BY 12(32.2) TO GET LBM
REMAINING UNITS IN
INCHES, SECONDS

1/7/87

Chuck: Use numbers in green.

TOTAL

RECOIL FORCE VS STROKE
WORST CASE



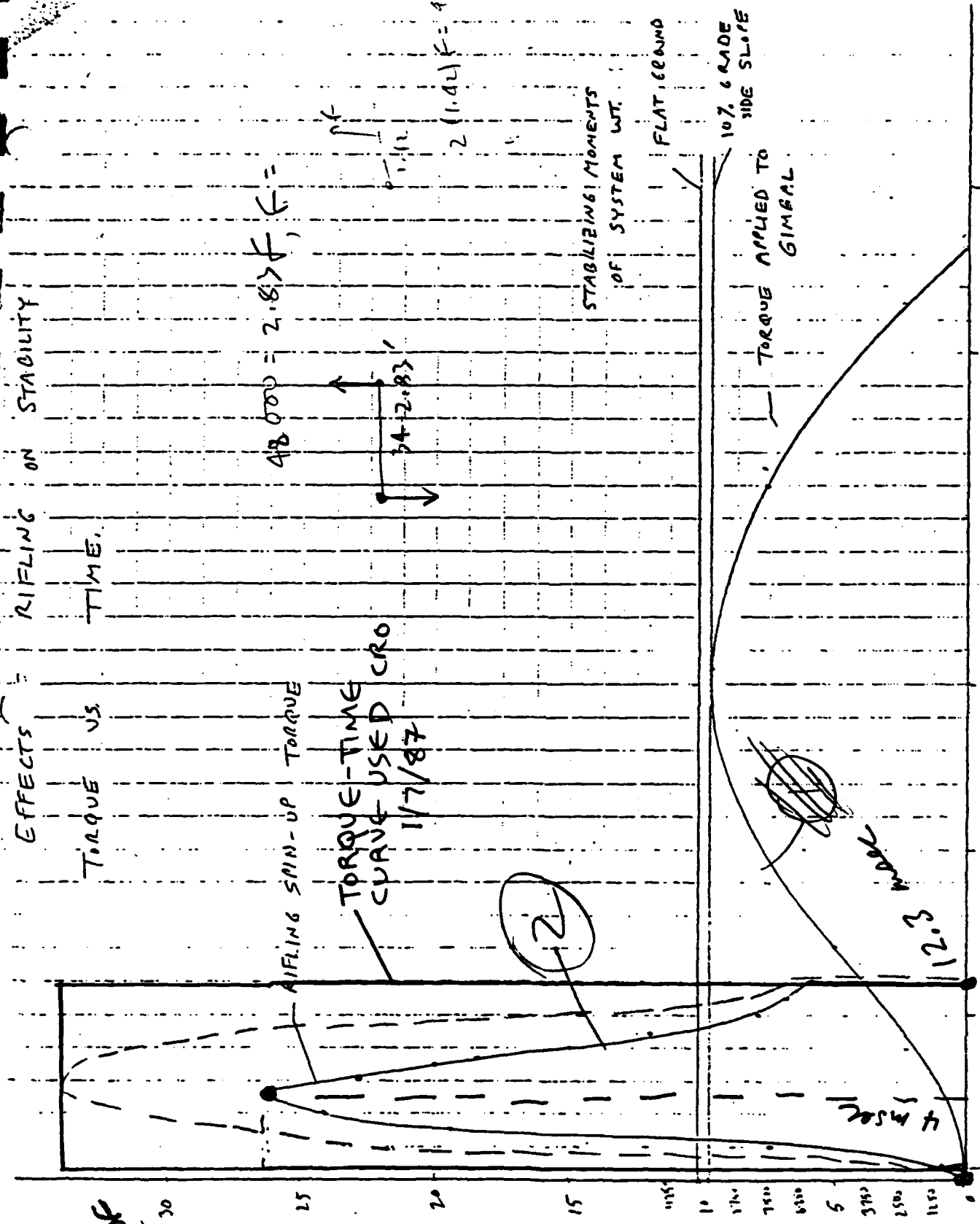
Note: Non-linear scale for time

Figure 4-2

48000 PROOF

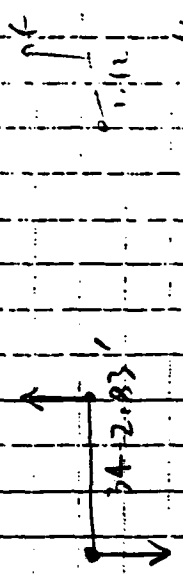
42,000
ft-# 25

Torque, FT-LB x 1000



EFFECTS OF TORQUE VS. RIFLING ON STABILITY TIME.

$$48,000 = 2.83 \times f, f =$$



$$2(1.12)f = 410$$

STABILIZING MOMENTS OF SYSTEM W.T.

FLAT, GRADE

10% GRADE

TORQUE APPLIED TO GIMBAL

6.0

50 1/4, 13

40 21.55

30 1.68

20 1.01

10 1.19

RECOIL DIST. FT.

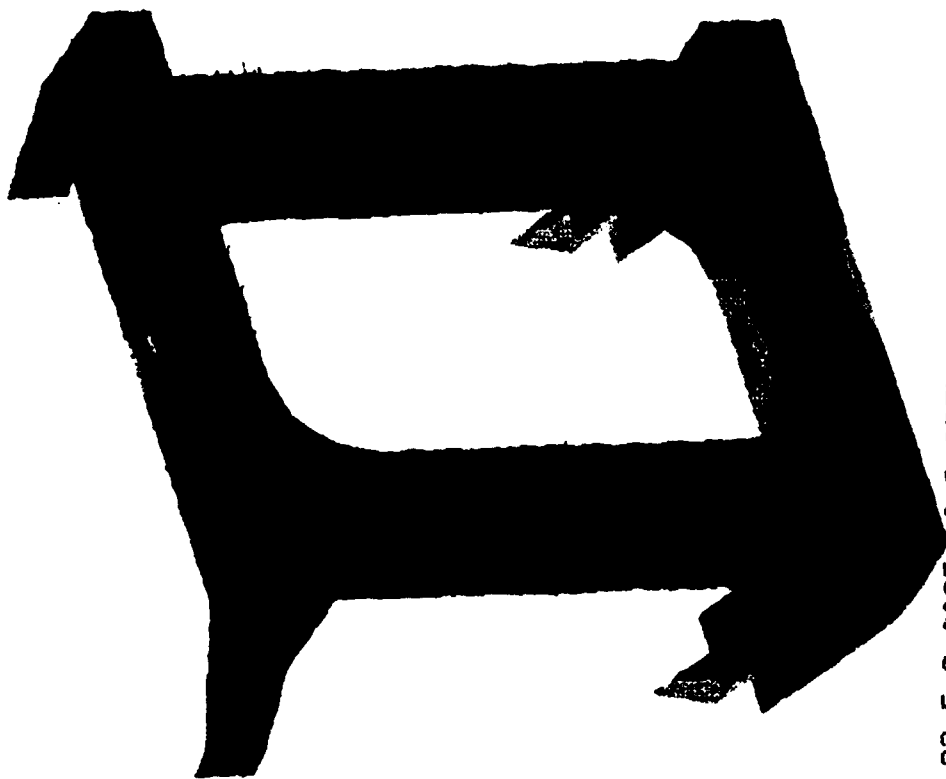
TIME, MSEC FROM START OF RIFLING

Additional
Transparencies

/VIEW, 1, -1, 1, 1
/ANGLE, 1, 0
CRO

ANSYS 4.28
 JAN 7 1987
 15:19:19
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.081
 SIGE
 TOP

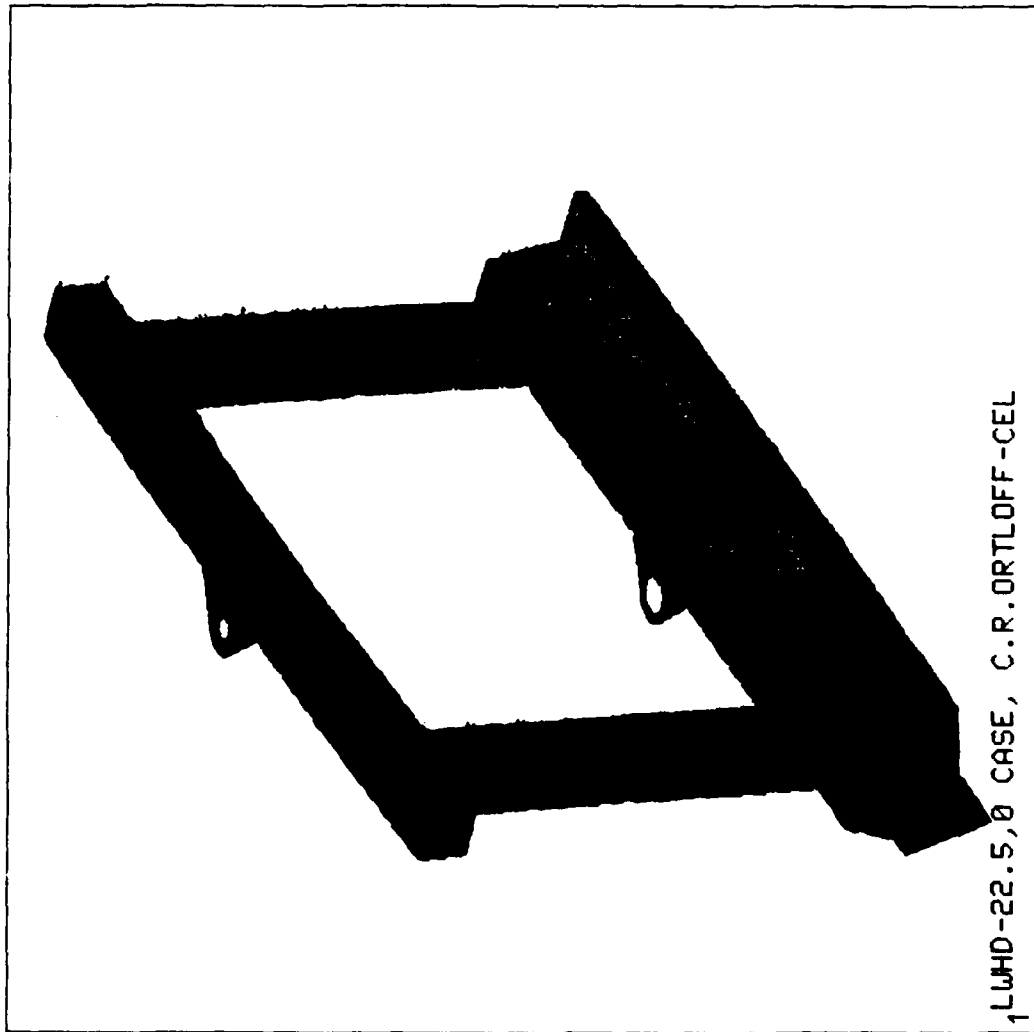
XU=-1.5
 YU=1
 ZU=1
 DIST=32.4
 XF=53.2
 YF=33.3
 ZF=-7.92
 HIDDEN
 MX=170685
 MN=756
 19634
 38516
 111014
 132926
 151808
 170690



1LUND-22.5,0 CASE, C.R.ORTLOFF-CEL

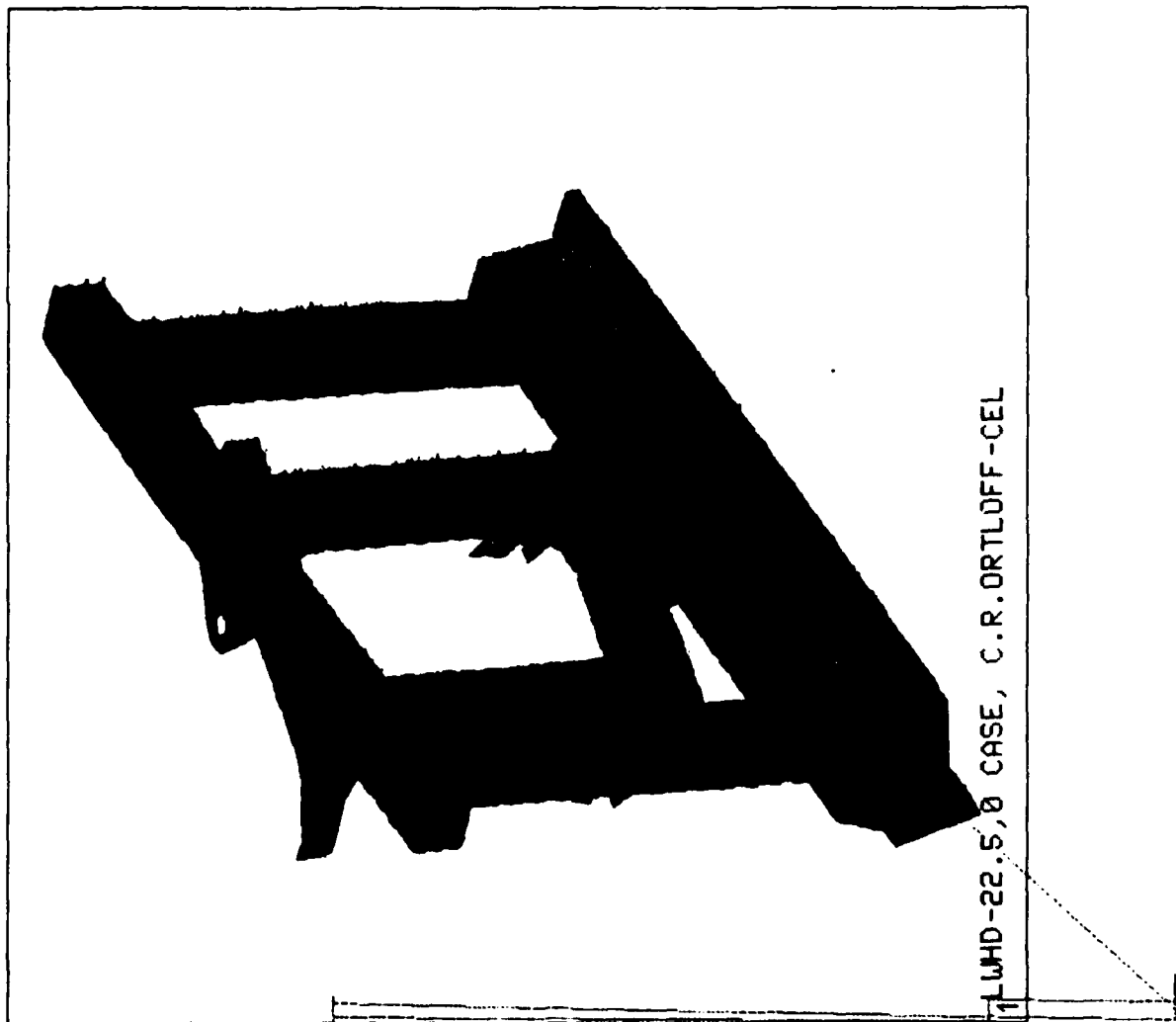


ANSYS 4.2B
 JAN 7 1987
 15:49:22
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.081
 SIGE
 TOP
 XU=-1.5
 YU=1
 ZU=1
 DIST=58.6
 XF=54.5
 YF=27.3
 ZF=4.98
 HIDDEN
 MX=132034
 MN=507
 15118
 29733
 44348
 58963
 73570
 88193
 102803
 117423
 132038



ANSYS 4.2B
JAN 7 1987
16:14:12
POST1 STRESS
STEP=1
ITER=1
TIME=.081
SIGE
TOP

XU=-1.5
YU=1
ZU=1
DIST=58.6
XF=54.5
YF=27.3
ZF=4.98
HIDDEN
MX=170685
MN=507
19415
33324
57000
76142
95051
113960
132869
151773
170687



D3/190

CEL MEMO: JANUARY 8, 1987

Interoffice

| | | | |
|---------|--|------|---|
| To | Larry Libhardt* | Date | January 8, 1987 |
| From | C. R. Ortloff | cc | E. Thuse R. Kazares A. Amberg J. Ries R. Rathe B. Anderson *81 figures only |
| Subject | STRESS STABILITY RESULTS FOR THE LTHD 22.5° GIMBAL ROTATION, 0° ELEVATION CASE UNDER PROOF LOADS | | |

Figures 385-466 present the results for the 22.5°-0° total system FE model under proof dynamic firing loads. System weight for the trails, gimbal, platform, cradle plus internals is computed to be 7890.27 lbf. Additional weight (not included in the FE model) includes wheels and wheel mount/retraction structures and miscellaneous attachments to bring total weight up to 9000 lbf.

The main conclusions of the present study are given below. Stress passes have been performed for 0.318, 0.018 and 0.081 sec. times.

- o The cradle (at a node on the forward manifold) undergoes about a 4 inch vertical motion when subject to firing loads. Cable tension appears to go to zero after about 0.375 sec. after firing initiates. It appears that cradle rigid body oscillations then occur (the cradle is suspended on the cable) at about 0.8 Hz (figure 388). The amplitude of these oscillations will damp rapidly due to the high damping constant of the Kevlar cable. Total longitudinal compression (figure 387) is not too far off the values for the more exact 29 lamina cradle FE model indicating that the frame representation for the cradle approximately duplicates the compressional stiffness. Longitudinal vibrational frequency for the cradle appears to be on the order of 5.5 Hz (figure 390).
- o Barrel-tip deflection (if the barrel remained stationary (which it does not)) is shown in figures 394-396. A component of the firing torque vector along the x-axis present for the 22.5° gimbal rotation case accounts for the barrel "jump" and subsequent near-rigid-body vibration of the cradle (as the cradle is suspended by a flexible cable from the first manifold and has a hinge mounting at the gimbal attachment end).
- o Side to side (UX) motion (figure 395) is also stimulated by the component of the firing torque vector in the Y direction. The maximum amplitude of this motion appears to be about 0.75 inch.
- o Figures 396-415 represent dynamic displacements at MDOF nodes on the platform and gimbal. A damping value of 0.2% is used. Reference to figure 386 gives the location of the MDOF nodes. These curves determine the time value selection for subsequent stress passes.

Stress Results for 0.318 sec. Stress Pass

- o The lower shaft openings on the gimbal lower box beam have local stresses about at the 80 ksi yield value; this zone (figure 425) should be locally reinforced.
- o The lower platform base plate (figure 427 and 436) shows large stress values over the yield stress. While this may be a result of the $U_Y=0$ BC applied to a limited number of nodes on the bottom side of this plate, nevertheless, reference to figures 432-434 indicates that the lower box beam to lower horizontal plate connection zone is highly stressed. Stresses in the triangular supports can reach 66 ksi (figure 434) in this zone. The lower platform plate may undergo local yielding if vertical ground pressure on this plate is not uniform. Figure 428 reinforces the idea that the forward and trailing parts of the horizontal ground spade plate is overstressed and may require thickening to lower stress levels.
- o Top and bottom tabs (figures 429-430) indicate low stress levels and are adequately designed as are the corner gimbal reinforcing tabs (figure 431).
- o A $U_X=0$ condition has been applied to the spade reinforcing plates (figure 435) to limit side travel present for rotated gimbal firing cases. Stresses in these spade reinforcements are low.
- o The gimbal lower arms show stress levels about half of yield stress (figure 437).

Stress Results for the 0.018 sec. Stress Pass

- o Again the horizontal spade plate indicates high stress values (figure 442) past the yield stress. It may be advisable to increase both the number and extension of the triangular reinforcement plates on both sides of the lower platform box beam to eliminate stress concentrations in the unsupported panel areas on this plate.
- o Again the triangular reinforcements between lower platform box beam and horizontal spade plate are highly stressed (figures 447-449); reinforcing according to the above suggestion is recommended.
- o The top and bottom tabs (figures 450-451) are adequately designed.
- o Again the gimbal shaft opening in the lower box beam needs reinforcement as local stresses exceed yield stress (figures 453-455).

Stress Results for the 0.081 sec. Stress Pass

- o Local stresses in the lower gimbal arms exceed yield stress (figure 456).
- o Local stress in the lower gimbal box beam shaft opening are 75% over yield stress; this zone requires local reinforcing.
- o The horizontal spade plate has stresses over yield similar to results from the other two stress pass cases (figure 461).
- o Top and bottom tabs appear to be adequately designed (figures 462-463).

A table of results is given below for stress in the upper and lower shafts:

| <u>Time</u> <u>(Sec)</u> | <u>Upper Shaft</u> <u>Max. Stress</u> | <u>Lower Shaft</u> <u>Max. Stress</u> |
|-----------------------------|--|--|
| 0.318 | 16 ksi | 29 ksi |
| 0.081 | 10.3 ksi | 34.6 ksi |

An estimate of dynamic forces on the trail-to-platform connecting pins indicates that for both times considered, a maximum of 2,500 lbf on each pin is a reasonable upper bound. This assumes a total of 4 connecting points for each trail to the platform.

Conclusions

Based on the results from the 0°-0°, 0°-72°, 22.5°-0° cases, the following recommendations are made:

- o Reinforce locally all the shaft opening zones on the gimbal and platform upper and lower box beams.
- o Reinforce the upper and lower gimbal arm sets.
- o Increase the number of triangular reinforcing plates connecting the lower box beam of the platform to the horizontal plate of the spade. An increase in size, number and thickness of these elements appears necessary.
- o Decrease the wall thickness of the vertical box beams in both gimbal and platform. The weight savings thus obtained can be redistributed to suggested reinforcements in other parts of the structure.
- o The present upper and lower gimbal to platform attachment shafts are structurally adequate as are the mount tabs.
- o The upper and lower shafts are adequately designed.

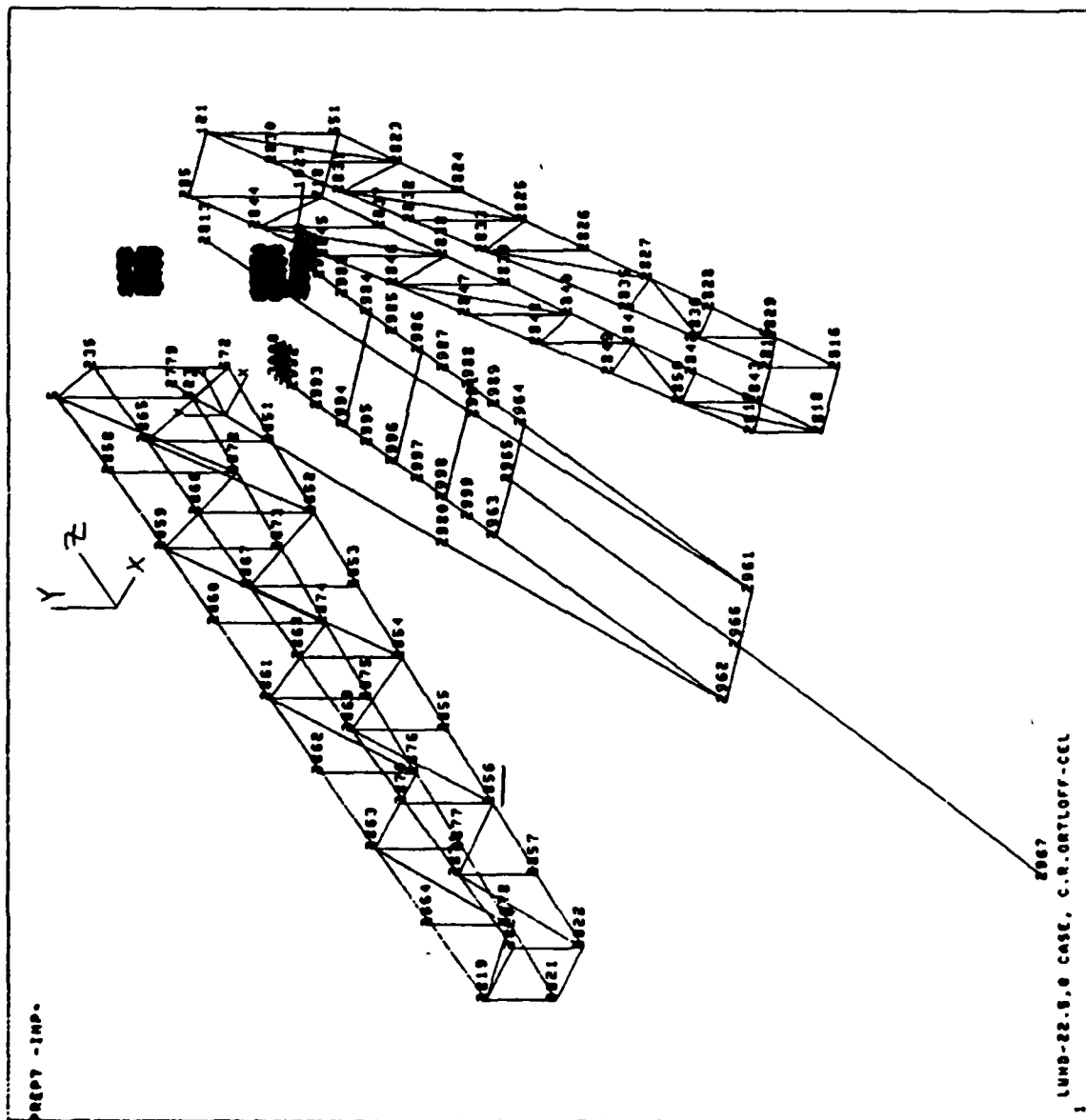
The degree to which reinforcement is necessary may be obtained by reference to the stress plots contained in previous memos (CRO to L. Libhardt, 17 Dec 86 and 29 Dec 86) and the maximum stresses for each case. As a "first approximation" rule the

stress may be changed linearly by varying the local thickness in the high stress region accordingly. For example, if maximum gimbal vertical box beam stress is 30 ksi, then a 50% reduction in wall thickness could be made with sufficient margin before yield stress values are encountered. This procedure may serve for redesign purposes on a first approximation level; however, a rerun of the modified FE model incorporating all the design changes is the best way to check that the desired lowering or redistribution of stress levels has been achieved.

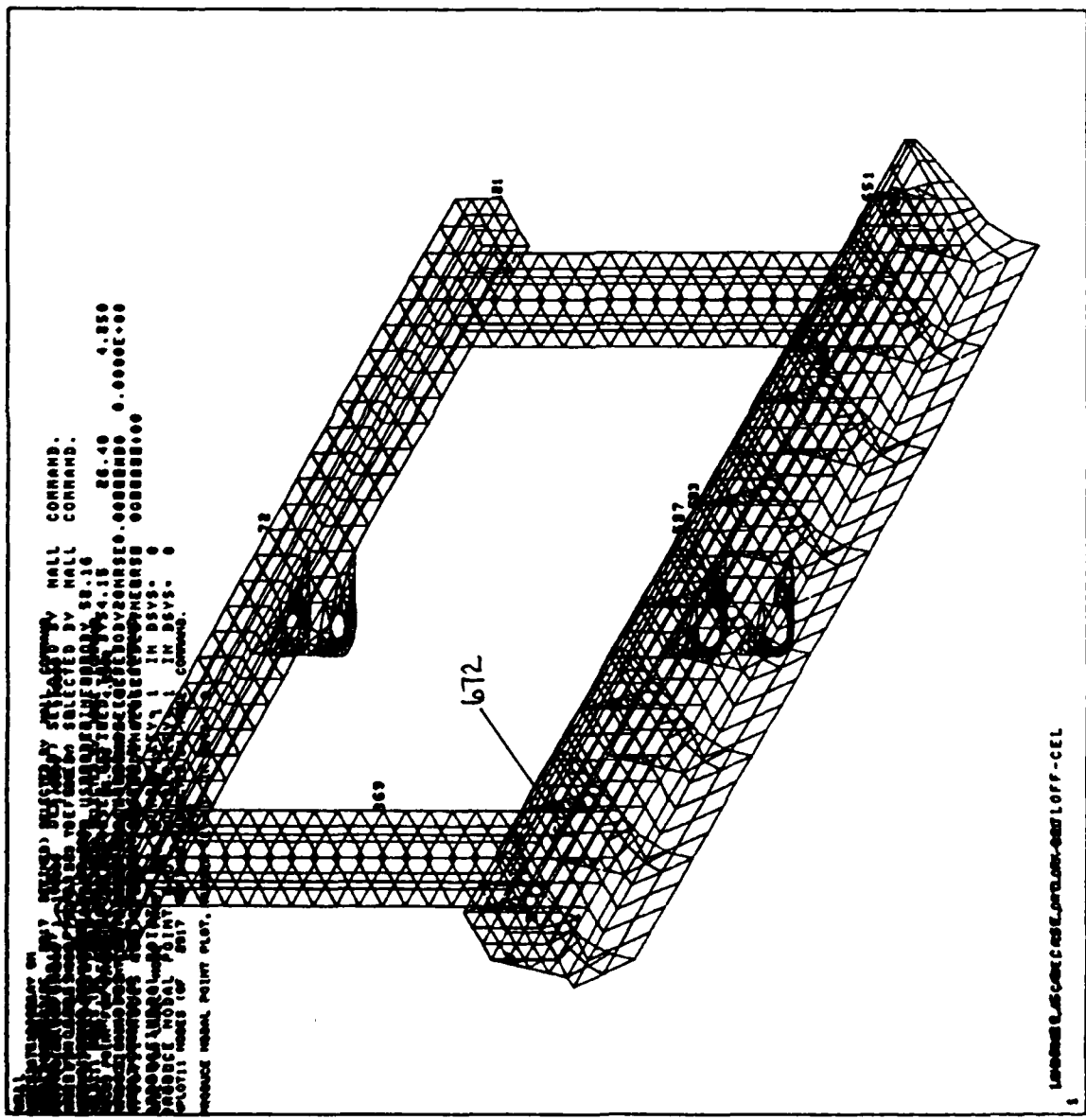


C. R. Ortloff

ANSYS 4.20
 JAN 5 1987
 9:18:16
 PREP7 ELEMENTS
 NHUM=1
 NU=0.1
 VU=0.1
 2U=1
 DIST=157
 NF=114
 VF=29.6
 ZF=174



NODE
 LISTING

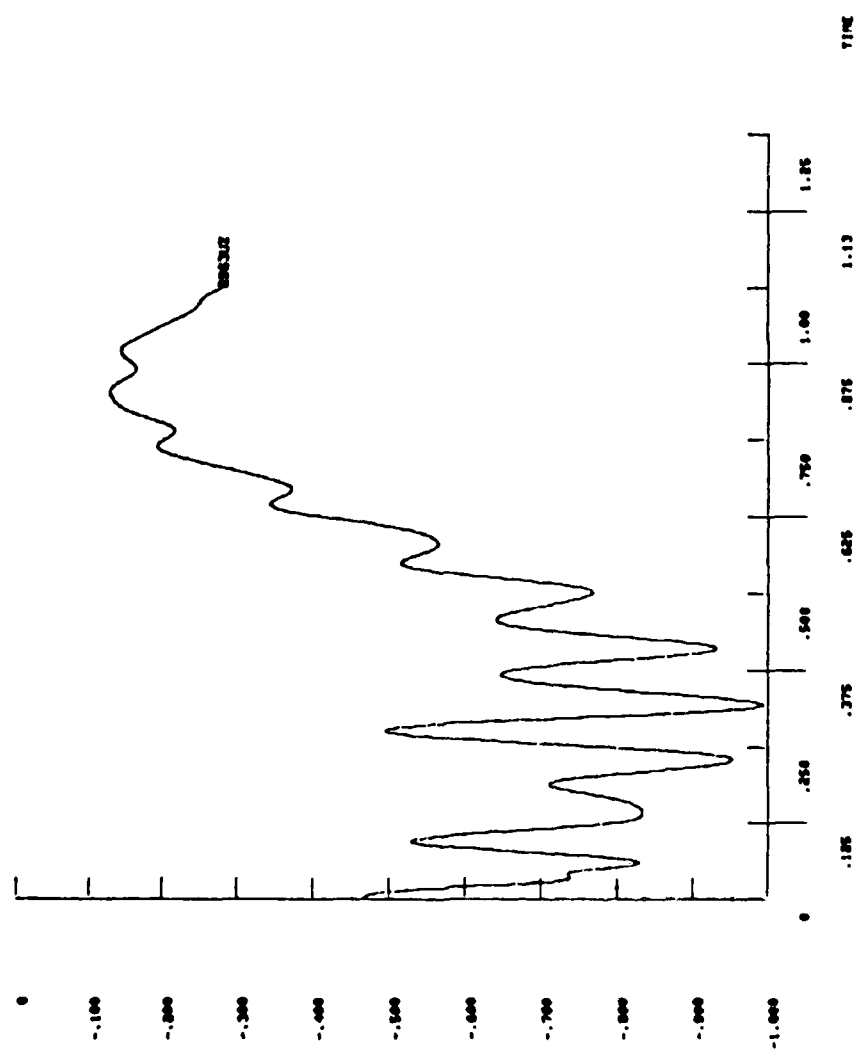


1. LAMINAR CASE CASE 1000-0001 OFF-CEL
 2. 26.49 0.0000E+00
 3. 26.49 0.0000E+00
 4. 26.49 0.0000E+00
 5. 26.49 0.0000E+00
 6. 26.49 0.0000E+00
 7. 26.49 0.0000E+00
 8. 26.49 0.0000E+00
 9. 26.49 0.0000E+00
 10. 26.49 0.0000E+00
 11. 26.49 0.0000E+00
 12. 26.49 0.0000E+00
 13. 26.49 0.0000E+00
 14. 26.49 0.0000E+00
 15. 26.49 0.0000E+00
 16. 26.49 0.0000E+00
 17. 26.49 0.0000E+00
 18. 26.49 0.0000E+00
 19. 26.49 0.0000E+00
 20. 26.49 0.0000E+00
 21. 26.49 0.0000E+00
 22. 26.49 0.0000E+00
 23. 26.49 0.0000E+00
 24. 26.49 0.0000E+00
 25. 26.49 0.0000E+00
 26. 26.49 0.0000E+00
 27. 26.49 0.0000E+00
 28. 26.49 0.0000E+00
 29. 26.49 0.0000E+00
 30. 26.49 0.0000E+00
 31. 26.49 0.0000E+00
 32. 26.49 0.0000E+00
 33. 26.49 0.0000E+00
 34. 26.49 0.0000E+00
 35. 26.49 0.0000E+00
 36. 26.49 0.0000E+00
 37. 26.49 0.0000E+00
 38. 26.49 0.0000E+00
 39. 26.49 0.0000E+00
 40. 26.49 0.0000E+00
 41. 26.49 0.0000E+00
 42. 26.49 0.0000E+00
 43. 26.49 0.0000E+00
 44. 26.49 0.0000E+00
 45. 26.49 0.0000E+00
 46. 26.49 0.0000E+00
 47. 26.49 0.0000E+00
 48. 26.49 0.0000E+00
 49. 26.49 0.0000E+00
 50. 26.49 0.0000E+00
 51. 26.49 0.0000E+00
 52. 26.49 0.0000E+00
 53. 26.49 0.0000E+00
 54. 26.49 0.0000E+00
 55. 26.49 0.0000E+00
 56. 26.49 0.0000E+00
 57. 26.49 0.0000E+00
 58. 26.49 0.0000E+00
 59. 26.49 0.0000E+00
 60. 26.49 0.0000E+00
 61. 26.49 0.0000E+00
 62. 26.49 0.0000E+00
 63. 26.49 0.0000E+00
 64. 26.49 0.0000E+00
 65. 26.49 0.0000E+00
 66. 26.49 0.0000E+00
 67. 26.49 0.0000E+00
 68. 26.49 0.0000E+00
 69. 26.49 0.0000E+00
 70. 26.49 0.0000E+00
 71. 26.49 0.0000E+00
 72. 26.49 0.0000E+00
 73. 26.49 0.0000E+00
 74. 26.49 0.0000E+00
 75. 26.49 0.0000E+00
 76. 26.49 0.0000E+00
 77. 26.49 0.0000E+00
 78. 26.49 0.0000E+00
 79. 26.49 0.0000E+00
 80. 26.49 0.0000E+00
 81. 26.49 0.0000E+00
 82. 26.49 0.0000E+00
 83. 26.49 0.0000E+00
 84. 26.49 0.0000E+00
 85. 26.49 0.0000E+00
 86. 26.49 0.0000E+00
 87. 26.49 0.0000E+00
 88. 26.49 0.0000E+00
 89. 26.49 0.0000E+00
 90. 26.49 0.0000E+00
 91. 26.49 0.0000E+00
 92. 26.49 0.0000E+00
 93. 26.49 0.0000E+00
 94. 26.49 0.0000E+00
 95. 26.49 0.0000E+00
 96. 26.49 0.0000E+00
 97. 26.49 0.0000E+00
 98. 26.49 0.0000E+00
 99. 26.49 0.0000E+00
 100. 26.49 0.0000E+00

PREP7 ELEMENTS
 XU=-1
 YU=-1
 ZU=1
 DIST=50.2
 XF=54.2
 YF=26.4
 ZF=4.85
 PREP7 NODES
 XU=-1
 YU=-1
 ZU=1
 DIST=50.2
 XF=54.2
 YF=26.4
 ZF=4.85
 PREP7 NODES
 XU=-1
 YU=-1
 ZU=1
 DIST=50.2
 XF=54.2
 YF=26.4
 ZF=4.85
 PREP7 NODES
 XU=-1
 YU=-1
 ZU=1
 DIST=50.2
 XF=54.2
 YF=26.4
 ZF=4.85
 PREP7 NODES
 XU=-1

MDof
 NODES

RECORD COMPLETE FOR 1001 DATA POINTS
 SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES
 LAST TIME IDENTIFIED NAME MINIMUM AT TIME MAXIMUM AT TIME
 0 316P 0003 UZ 000306 -0.0036 0.3100 -0.1076 0.0000
 007 000310 000310
 000310 000310
 000310 000310



LUMP-22 5.0 CORN, C.R. OUTFLOW-CEL

DYNAMIC
 DISPLACEMENT-
 TIME HISTORY

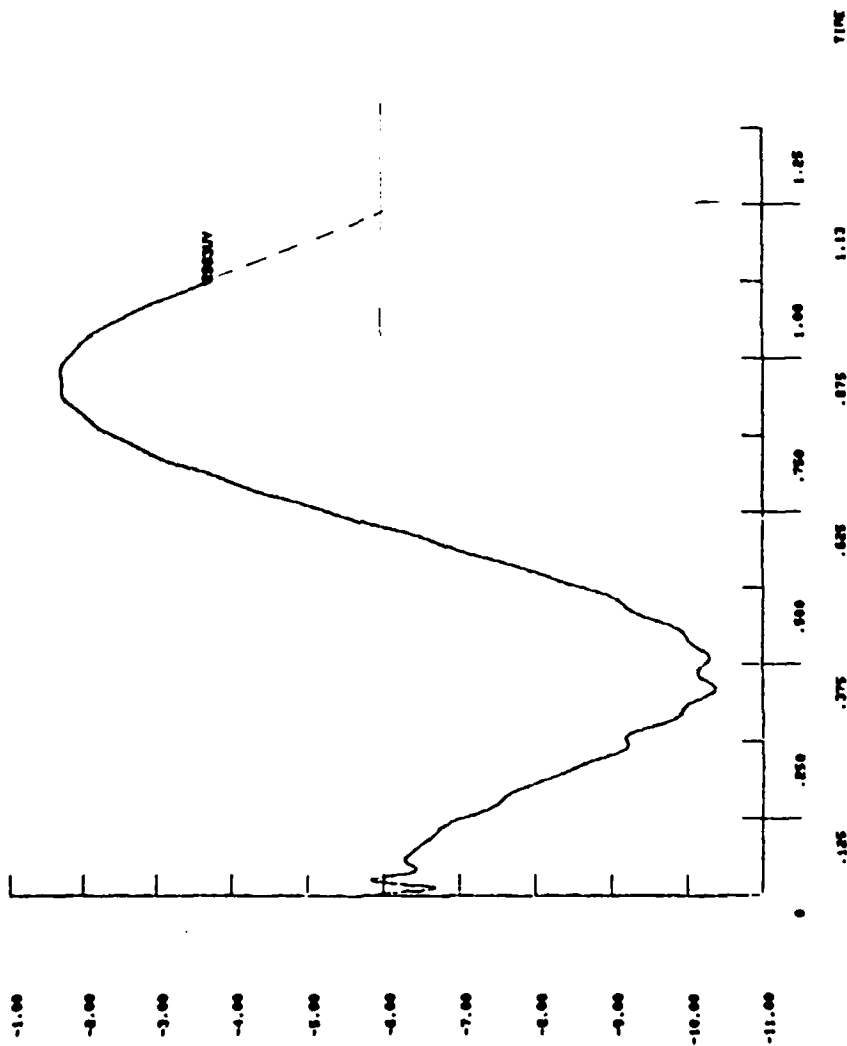
POSTER
 20-1
 0107-1.30

PERMANENTLY FOR 1001 DATA POINTS

ANALYSIS OF INDICATED STOPS THIS STOP AND EXTREME VALUES
 NOT THE INDICATED STOP AT TIME MINIMUM AT TIME

0 STOP 0003 UV 000000 -10.37 0.3340 -1.000 0.0040

PLT 0000000000
 PLT 0000000000
 PLT 0000000000



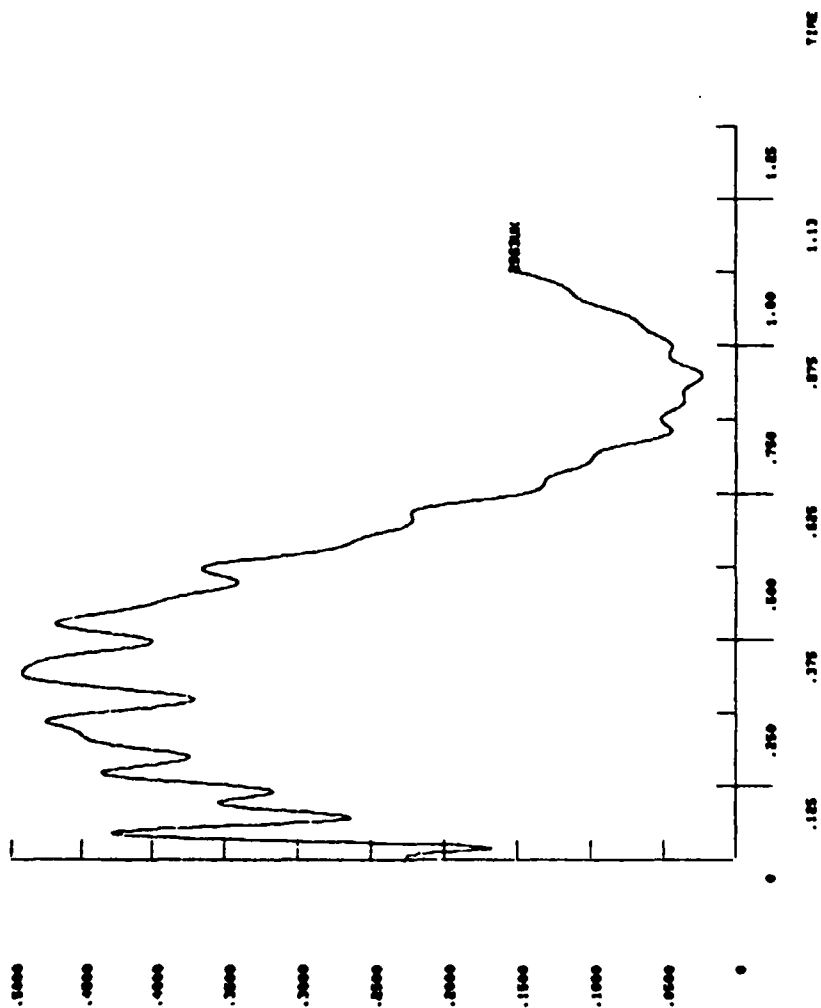
1 LAMB-00.0.0 CASE, C. P. CONT. OFF-CEL

000700
 20-1
 0107-1.20

FORM 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES
 LAST TIME IDENTIFIED HERE MINIMUM AT TIME MAXIMUM AT TIME
 2 310P 2043 IN 000300 0.0017E-01 0.0000 0.4001 0.3170

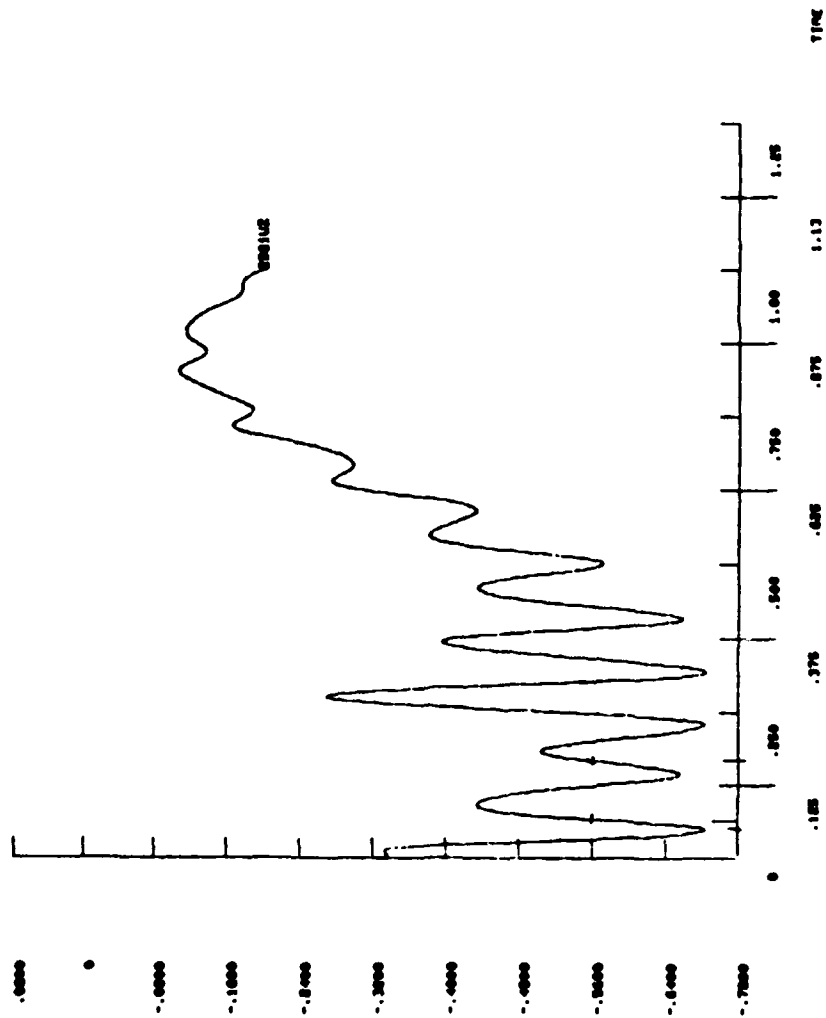
LAST IDENTIFICATION
 SAME VARIABLE VALUE
 0 000300



1 1000-20.5.0 CODE, C.A. 001077-CEL

POSTER
 20-1
 0107-1.03

RECORDS TEMP/ATM FOR 1001 DATA POINTS
 NUMBER OF UNUSABLE STAGES THIS STAGE AND EXTREME VALUES
 MAXIMUM IDENTIFICATION NUMBER MINIMUM AT TIME MAXIMUM AT TIME
 0.0100 0.0100 0.0100 -0.0040 0.3100 -0.1000 0.0000
 MAX IDENTIFICATION NUMBER
 MAX IDENTIFICATION NUMBER

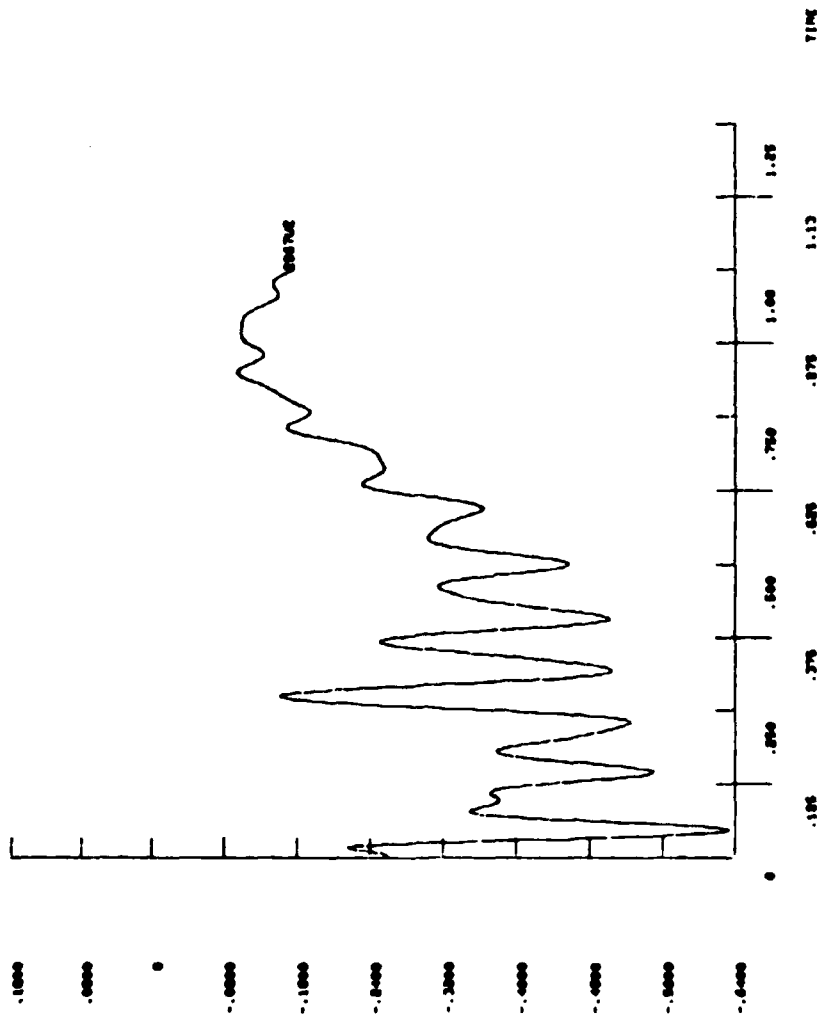


1.0000-0.0000 C.A. 0.0100-0.0100

POSTAGE
 24-1
 DIST-1.43

FORMER COMPLETE FOR 1001 DATA POINTS
 PROPERTY OF UNCLASSIFIED FROM THIS STEP AND EXTENDING VALUES
 MAX TIME IDENTIFIED FROM MINIMUM AT TIME MAXIMUM AT TIME
 0.0100 0.0100 0.0100 -0.0100 0.0100 0.0100 0.0100 0.0100 0.0100 0.0100

PLANT IDENTIFICATION NUMBER
 PLANT IDENTIFICATION NUMBER

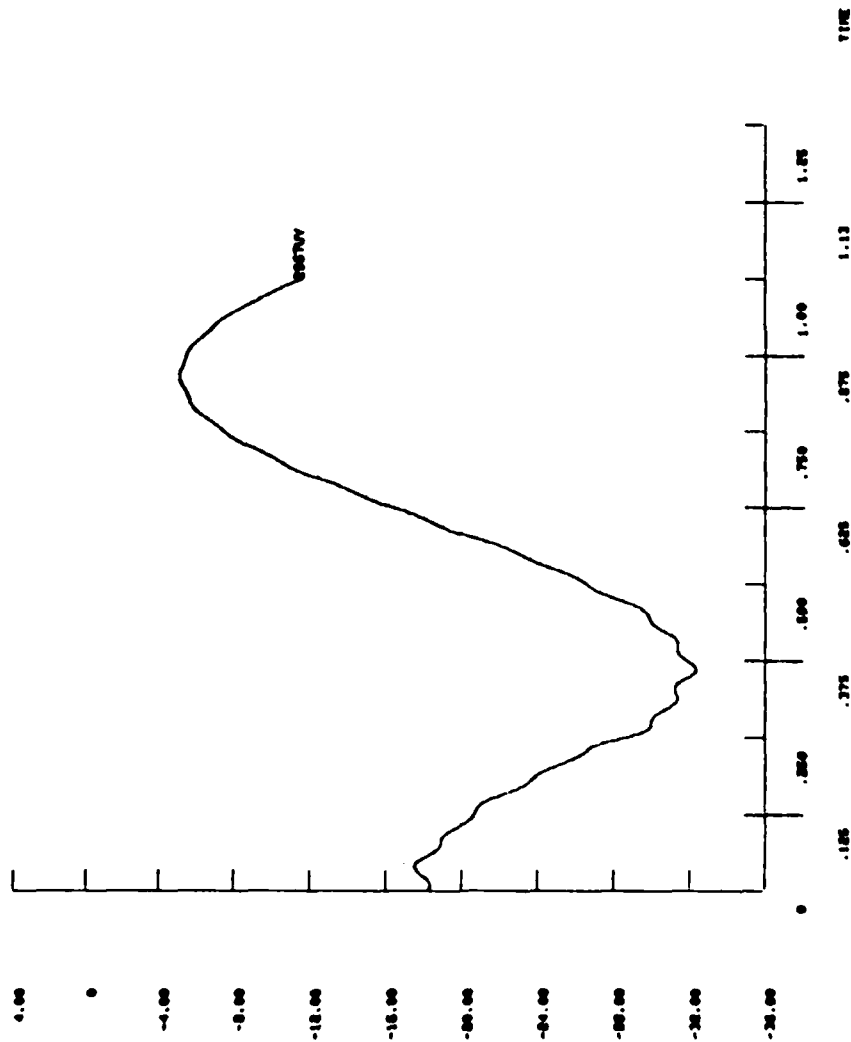


LAMB-40.5.0 CASE, C.A. 0071007-CEL

POSTER
 20-1
 DIST-1.43

BARREL TIP

SUMMARY OF TEST DATA POINTS
 NUMBER OF UNSTABLE STRESS THIS STEP AND EXTREME VALUES
 MAX TYP TENSILE STRESS MAX MINIMUM AT TIME MAXIMUM AT TIME
 0.010 0.007 0.007 0.007 0.000 0.000 0.000 0.000
 MAX TYP TENSILE STRESS MAX MINIMUM AT TIME MAXIMUM AT TIME
 0.010 0.007 0.007 0.007 0.000 0.000 0.000 0.000



LOAD-05.0 CASE. C.R. CONTROLLED

POSTER
 20-1
 0187-1.20

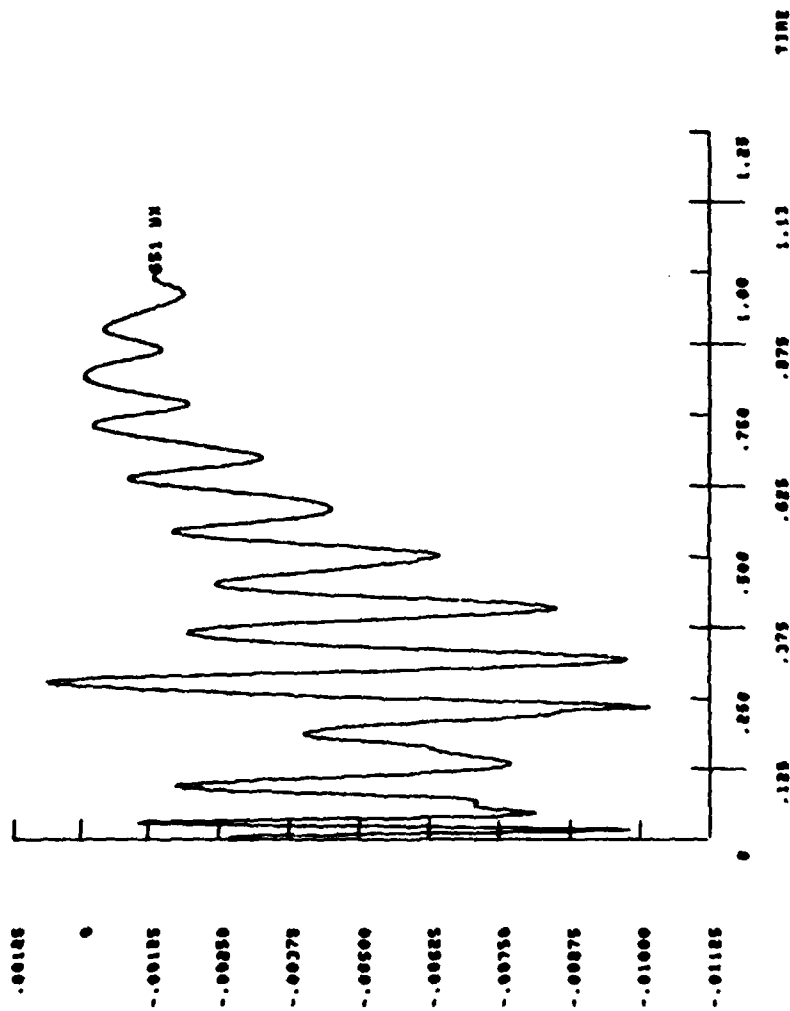
BARREL TIP

*****COMPLETE FOR 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES
 NAME TYPE IDENTIFIER NAME MINIMUM AT TIME MAXIMUM AT TIME

0 0100 001 UN 001 UN -0.1010E-01 0.0340 0.0100E-03 0.0770

END DEFINITION
 NAME
 CURVE VARIABLE 001 UN

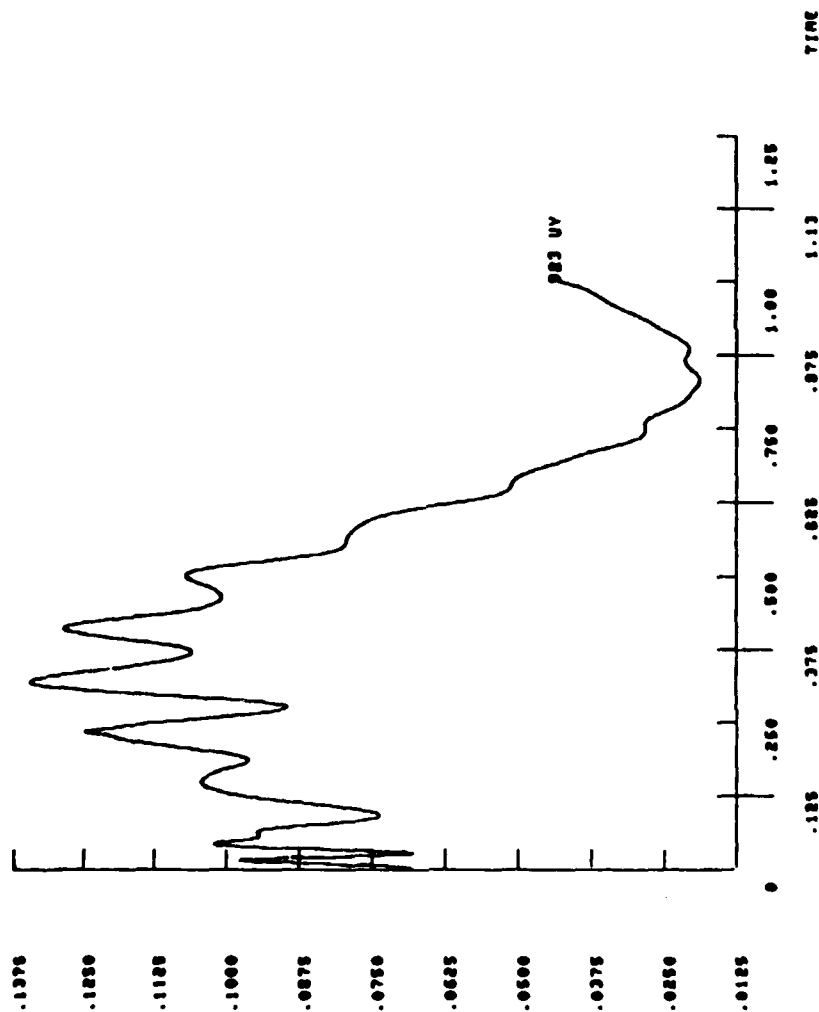


1 LUMP-22.8.0 CASE. C.R.00100FF-CEL

*****COMPLETE FOR 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES
 1001 TYPE IDENTIFIERS NAME MINIMUM AT TIME MAXIMUM AT TIME
 2 818P 983 UV 983 UV 0.1885E-01 0.0310 0.1344 0.3180

PLOT DEFINITION
 CURVE VARIABLE NAME
 1 2 983 UV



1 LUMB-22.5.0 CASE, C.R.ORTLOFF-CEL

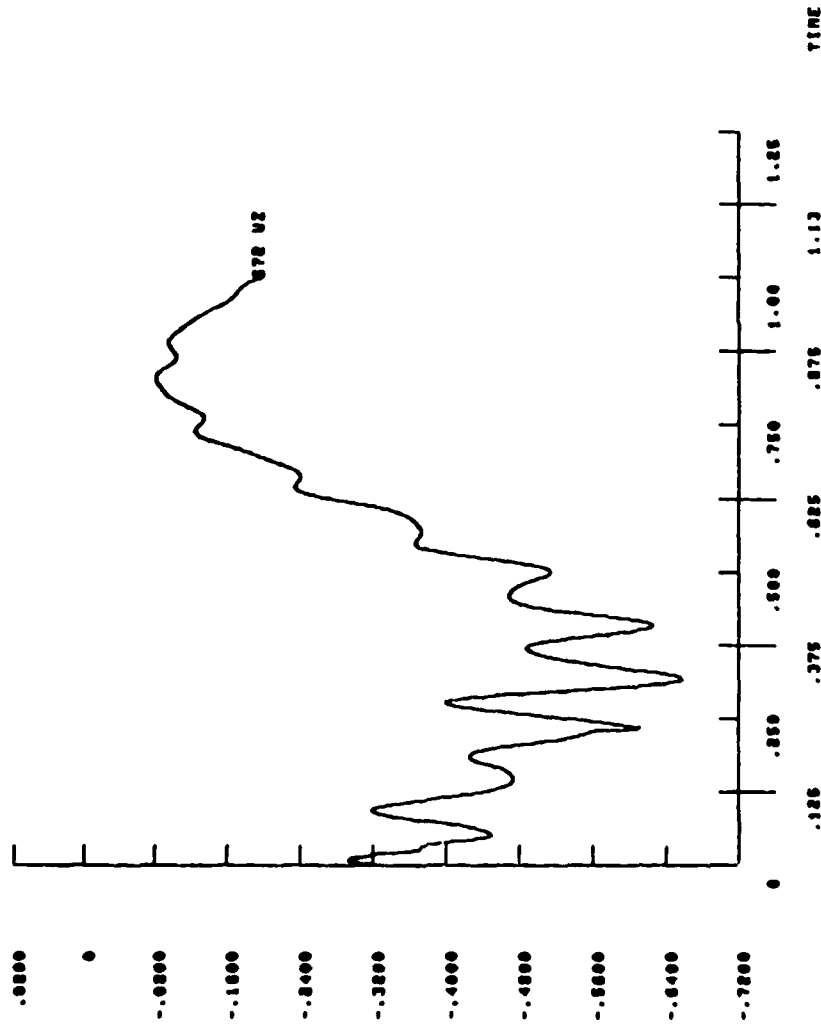
INCOMPLETE FOR 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES

NAME TYPE IDENTIFIERS NAME MINIMUM AT TIME MAXIMUM AT TIME

2 DISP Q2A UZ 678 UZ -0.6877 0.3180 -0.6187E-01 0.0280

PLOT DEFINITION
CURVE VARIABLE NAME
1 678 UZ



1 LUND-82.5.0 CASE, C.R.ORTLOFF-CEL

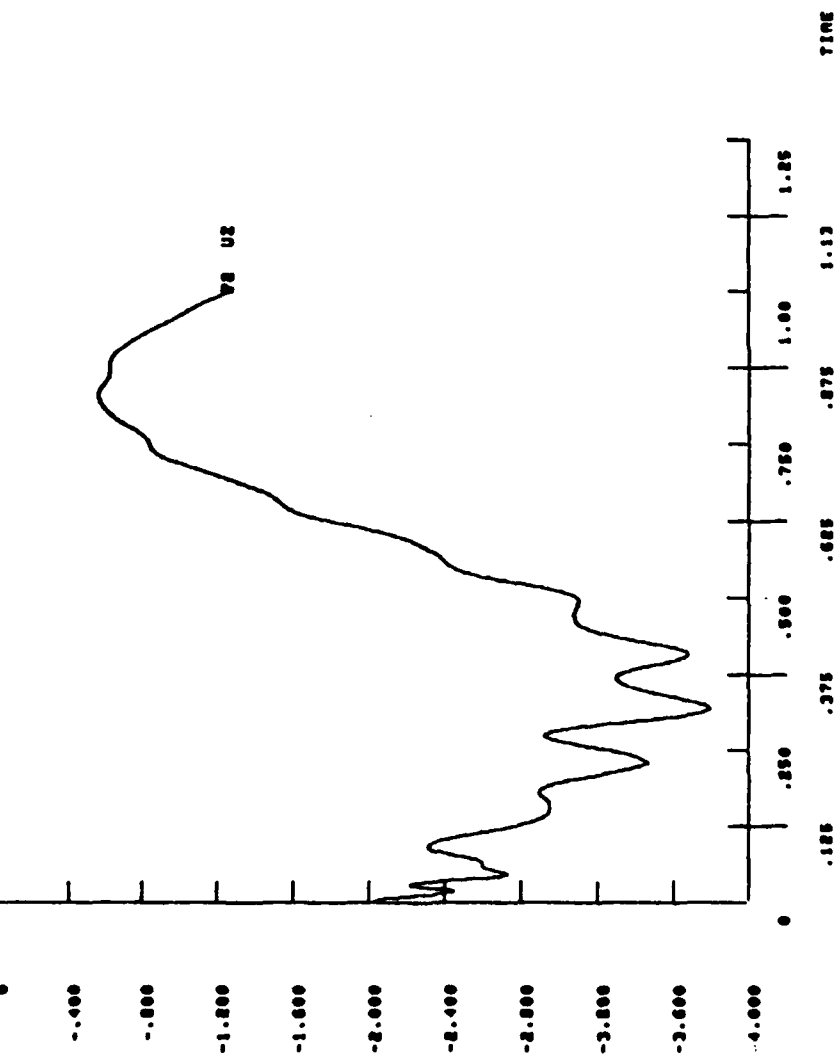
1 LUMB-22.5.0 CASE, C.R.08710FF-CEL

INCOMPLETE FOR 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES

| VARIABLE IDENTIFIERS | NAME | MINIMUM | AT TIME | MAXIMUM | AT TIME |
|----------------------|------|---------|---------|---------|---------|
| 2 DISP | U2 | -3.703 | 0.3100 | -0.0506 | 0.0000 |

PLOT DEFINITION
CURVE VARIABLE NAME
1 2 U2



1 LUND-22.5.0 CASE, C.R. ONTLOFF-CEL

| NAME | TYPE | IDENTIFIERS NAME | MINIMUM | AT TIME | MAXIMUM | AT TIME |
|--|------|------------------|---------|---------|---------|---------|
| SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES | | | | | | |

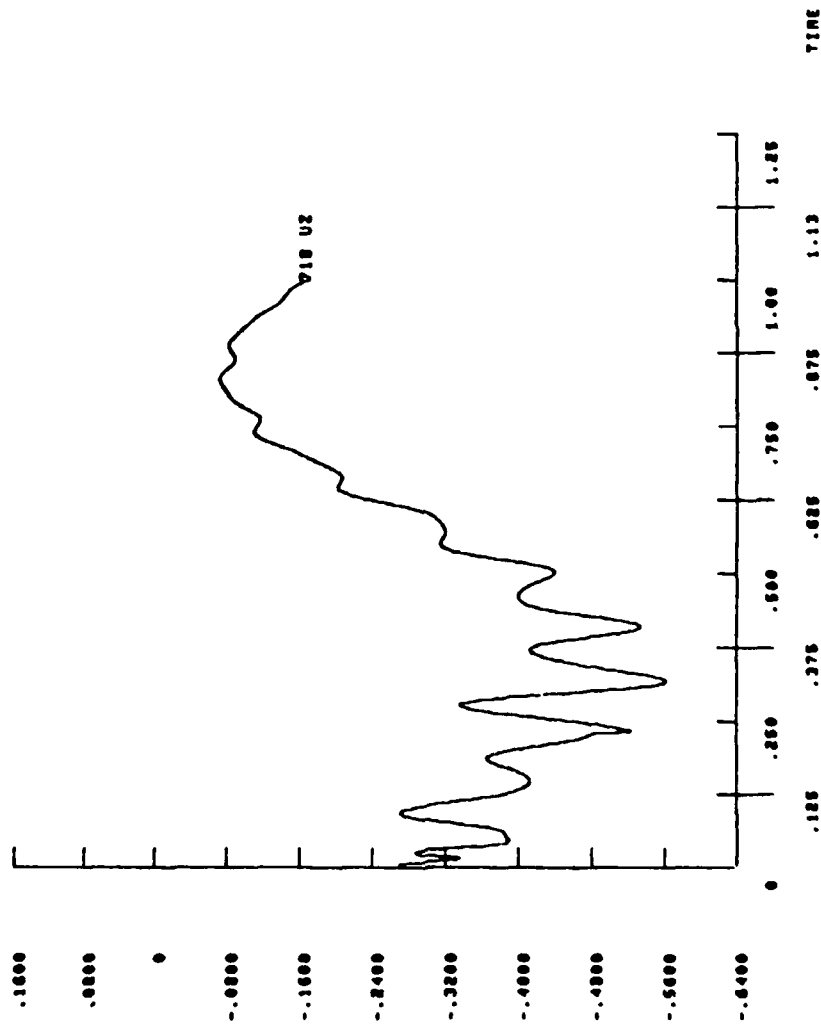
| DATA TYPE | IDENTIFIERS | MINIMUM | AT TIME | MAXIMUM | AT TIME |
|--|-------------|---------|---------|---------|---------|
| SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES | | | | | |

| | | | | | | |
|--------|----------|--------|---------|--------|-------------|--------|
| 0 018P | 71A,, U2 | 710 U2 | -0.5619 | 0.3100 | -0.7853E-01 | 0.0200 |
|--------|----------|--------|---------|--------|-------------|--------|

| <div>PLOT DEFINITION</div> <div>CURVE VARIABLE</div> <div>1</div> | <div>NAME</div> <div>P10 UZ</div> |
|---|-----------------------------------|
| | |

| CURVE | VARIABLE | NAME |
|-------|----------|------|
|-------|----------|------|

2000



LUND-22.5.0 CASE, C.R.0876087-CEL

*****COMPLETE FOR 1001 DATA POINTS

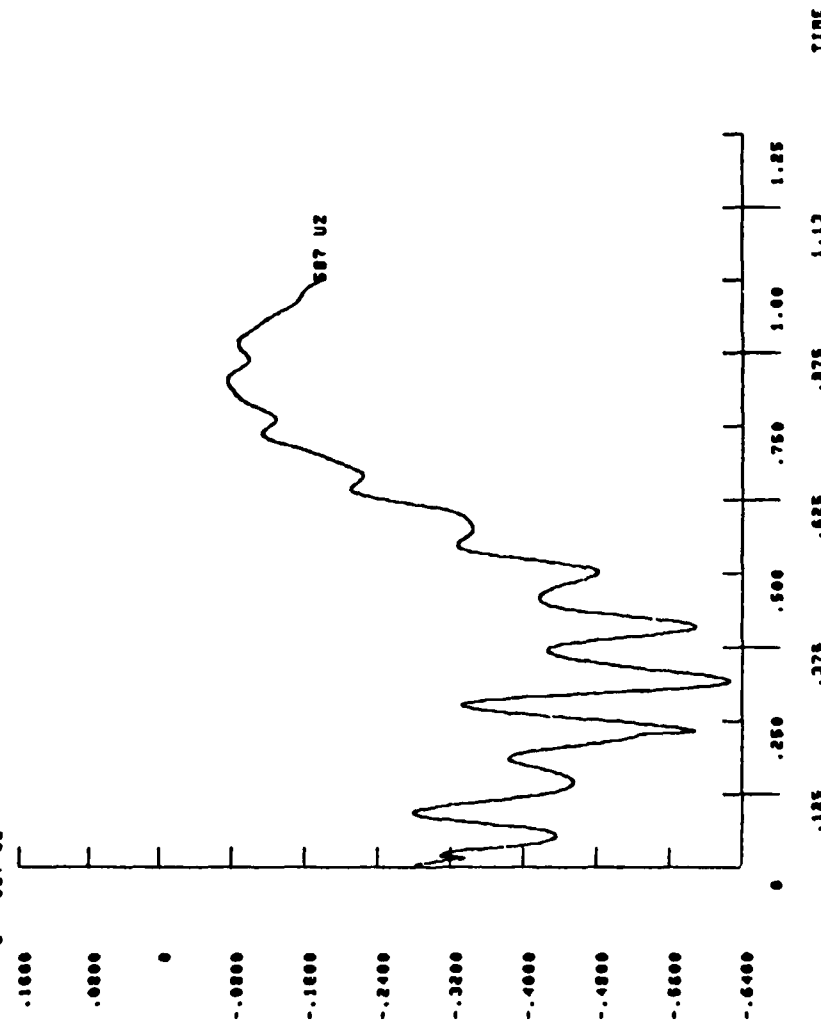
SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES
 NAME TYPE IDENTIFIERS NAME MINIMUM AT TIME MAXIMUM AT TIME

2 DISP VALU UZ 587 UZ -0.6282 0.3180 -0.7439E-01 0.8280

PLOT DEFINITION

CURVE VARIABLE NAME

1 CURVE VARIABLE 587 UZ

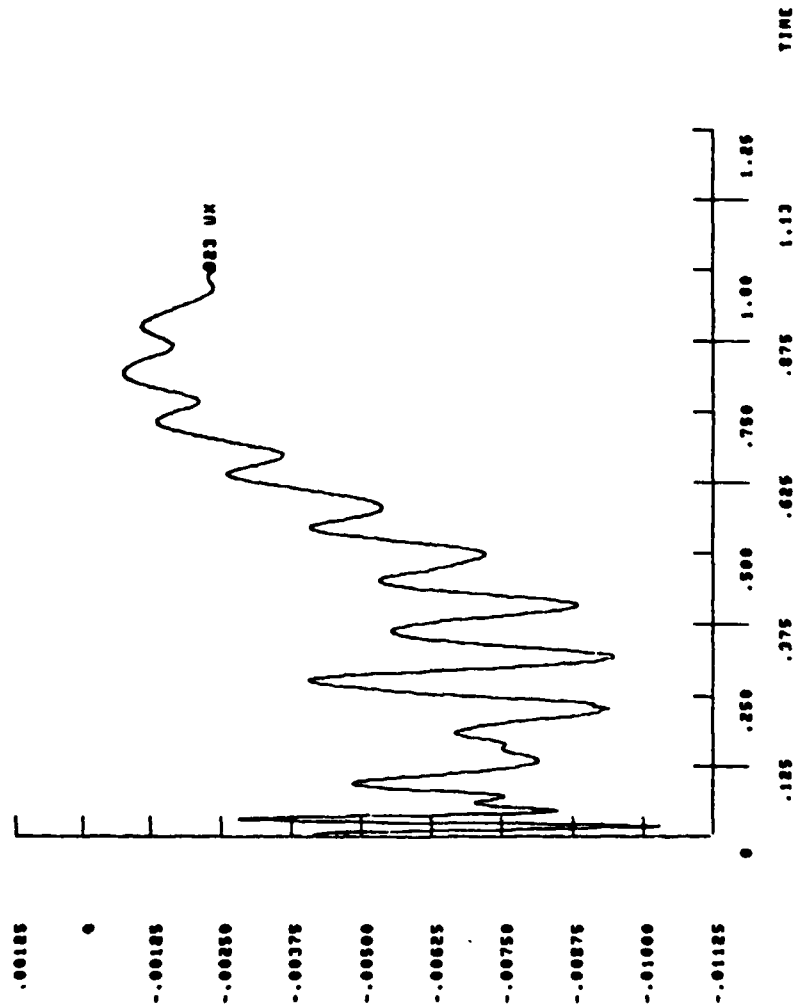


1 LUMB-22.5.0 CASE, C.R.ORTLOFF-CEL

POORER COMPLETE FOR 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES
 VAR1 TYPE IDENTIFIERS NAME MINIMUM AT TIME MAXIMUM AT TIME
 2 018P 023 UX 023 UX -0.1088E-01 0.1800E-01-0.7344E-03 0.8160

PLOT DEFINITION
 CURVE VARIABLE NAME
 1 2 023 UX

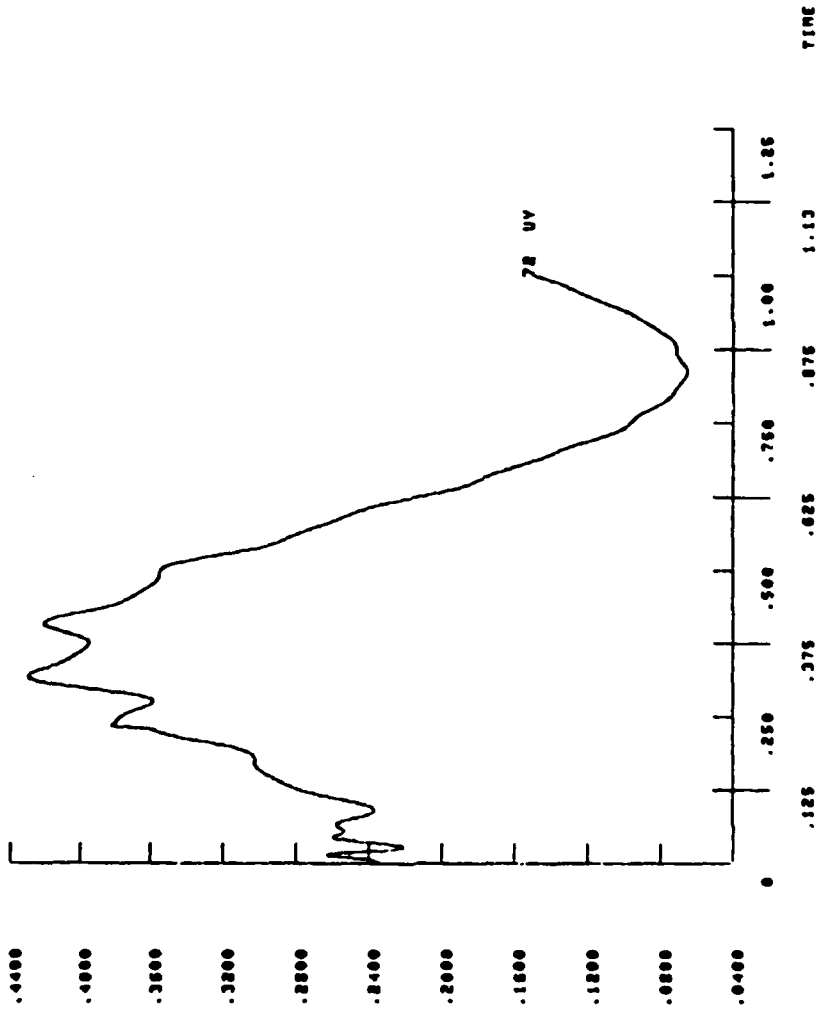


1 LUMB-22.5.0 CASE, C.R.ORTLOFF-CEL

PROGRAM COMPLETE FOR 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES
 NAME TYPE IDENTIFIERS NAME MINIMUM AT TIME MAXIMUM AT TIME
 Z DISP ZALU UV 72 UV 0.00000E-01 0.0300 0.4291 0.3100

PLOT DEFINITION
 CURVE VARIABLE 72 UV



1 LMD-28.5.0 CASE, C.R.ORTLOFF-CEL

INCOMPLETE FOR 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES

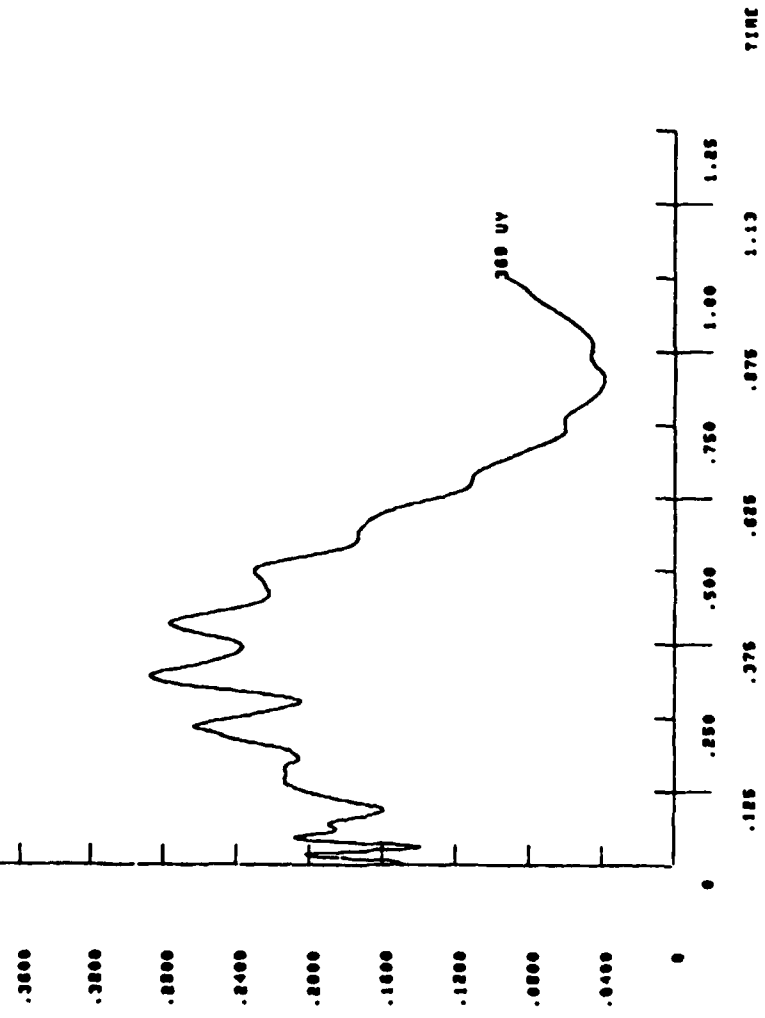
PART TYPE IDENTIFIERS NAME MINIMUM AT TIME MAXIMUM AT TIME

2 DISP 300 UV 300 UV 0.3884E-01 0.0000 0.8078 0.3100

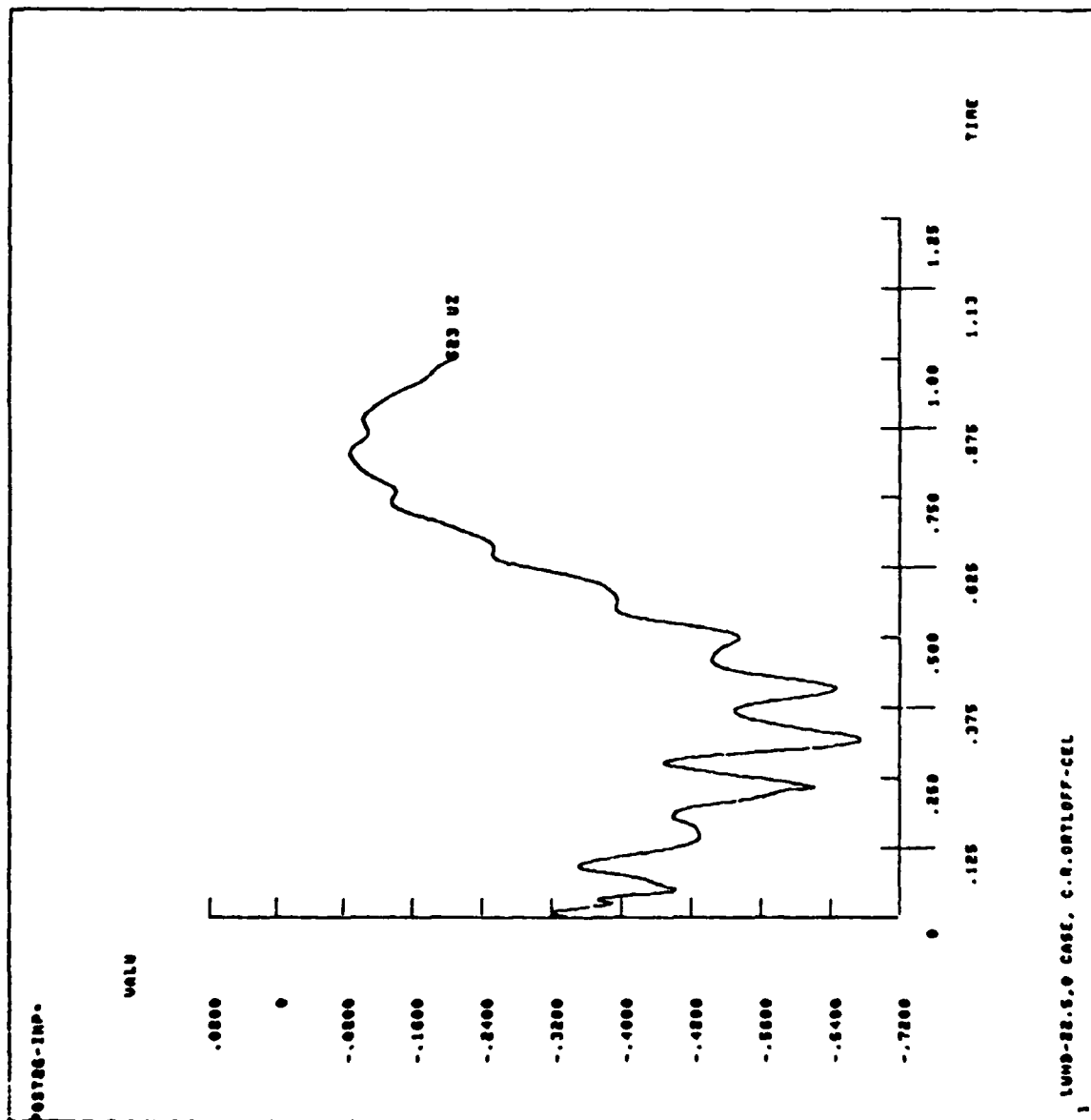
PLAT DEFINITION

CURVE VARIABLE NAME

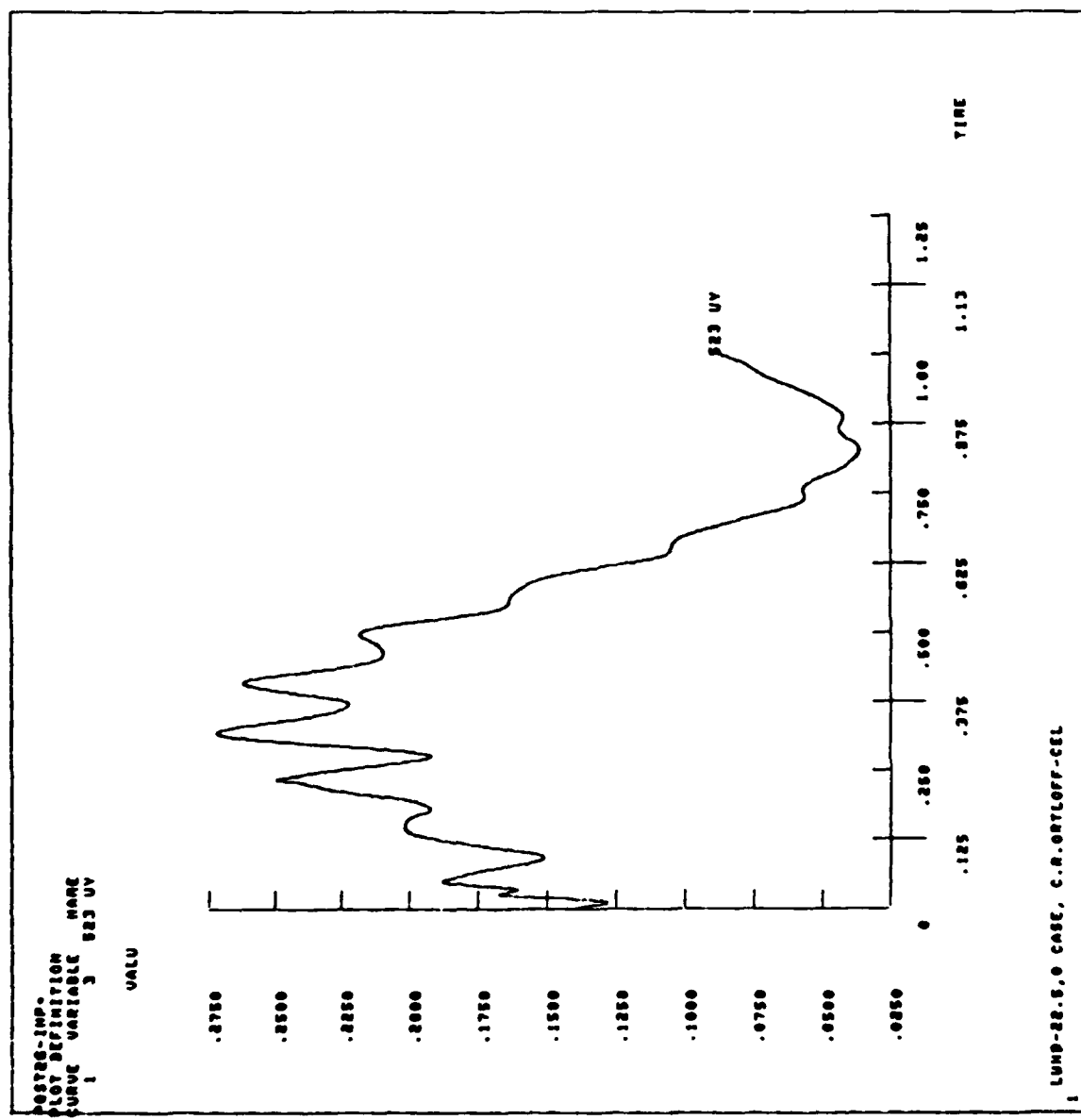
1 2 300 UV



1 LUND-28.5.0 CASE, C.R.ORTLOFF-CEL



POSTER
24-1
DIST-1.43



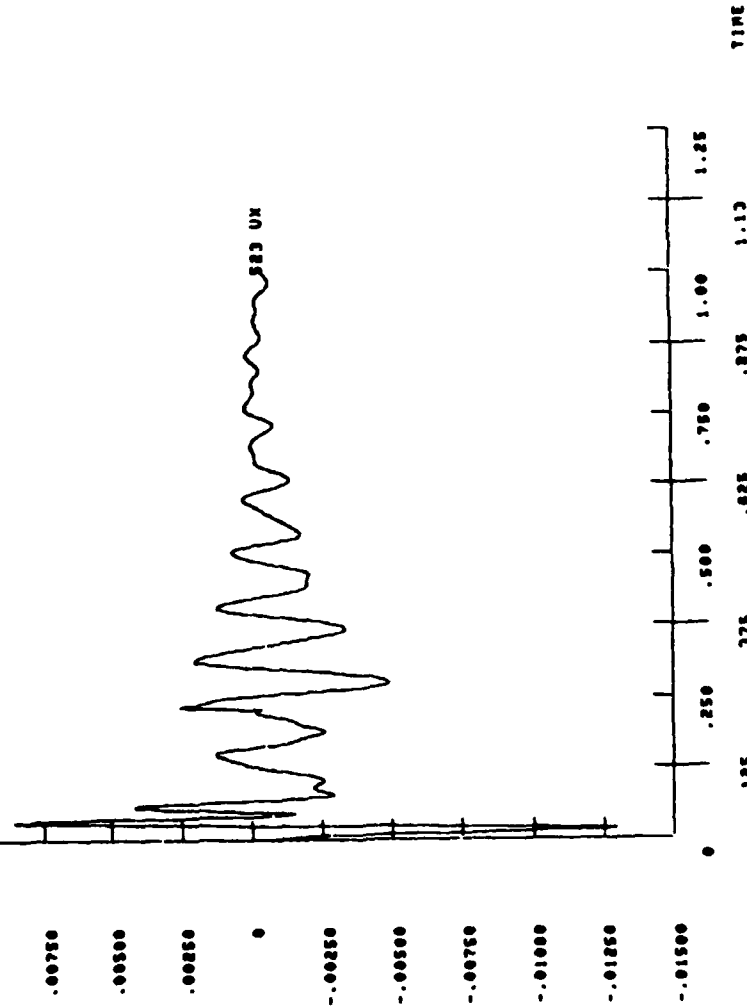
POSTER
 20-1
 9157-1.43

*****COMPLETE FOR 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES

| VARI TYPE | IDENTIFIERS | NAME | MINIMUM | AT TIME | MAXIMUM | AT TIME |
|-----------|-------------|--------|-------------|------------|-------------|------------|
| 8 | 81SP | 823 UX | -0.1891E-01 | 0.1900E-01 | 0.8897E-08 | 0.3808E-01 |
| 3 | 81SP | 823 UV | 0.3683E-01 | 0.8870 | 0.8720 | 0.3180 |
| 4 | 81SP | 823 UZ | -0.6748 | 0.3180 | -0.8720E-01 | 0.0280 |

PLOT DEFINITION
CURVE VARIABLE 823 UX



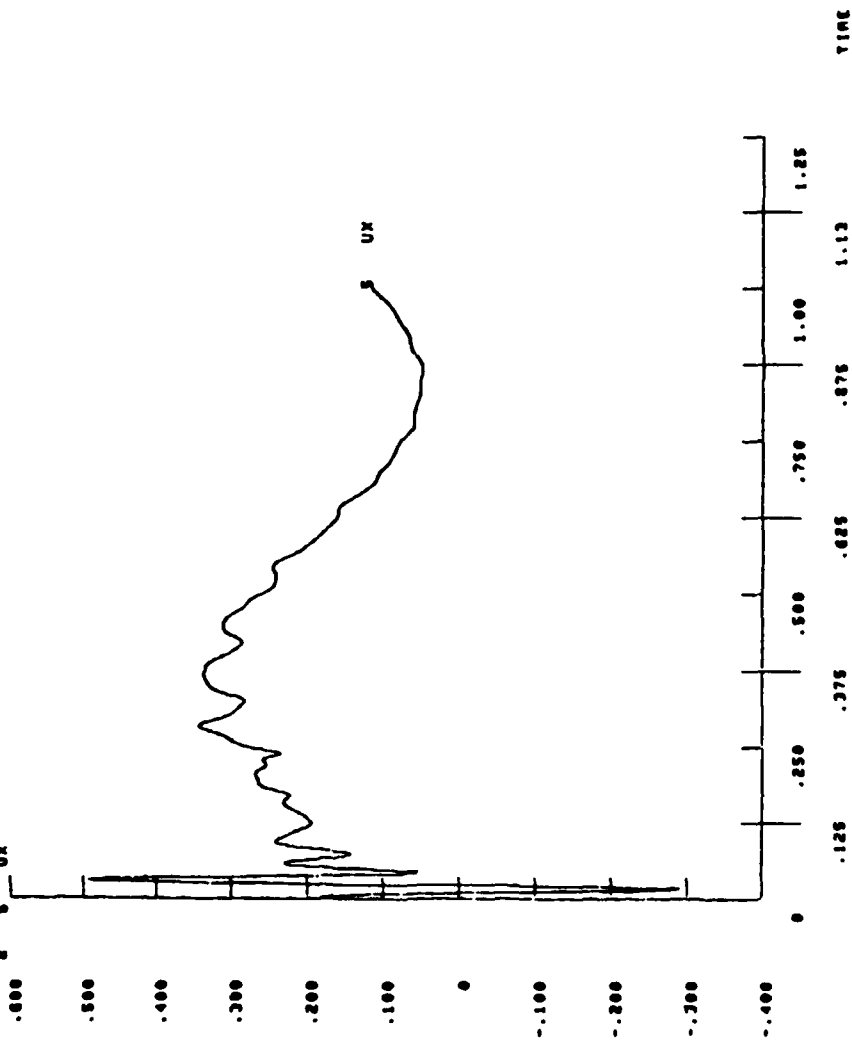
1 LUND-22.5.0 CASE, C.M.ORTLOFF-CEL

005726
ZU-1
0157-1.48

*****COMPLETE FOR 1001 DATA POINTS

SUMMARY OF VARIABLES STORED THIS STEP AND EXTREME VALUES
 NAME TYPE IDENTIFIERS NAME MINIMUM AT TIME MAXIMUM AT TIME
 2 DISP ONLY UX S UX -0.8897 0.1000E-01 0.4910 0.2000E-01

PLOT DESCRIPTION
 CURVE VARIABLE NAME
 1 2 S UX



1 LUMB-28.5.0 CASE, C.R.ORTLOFF-CEL

POST26
 24-1
 DIST-1.30

100-20.0.0 CASE, C.A. CARTER-CEL

POSTED
20-1
9137-1-20

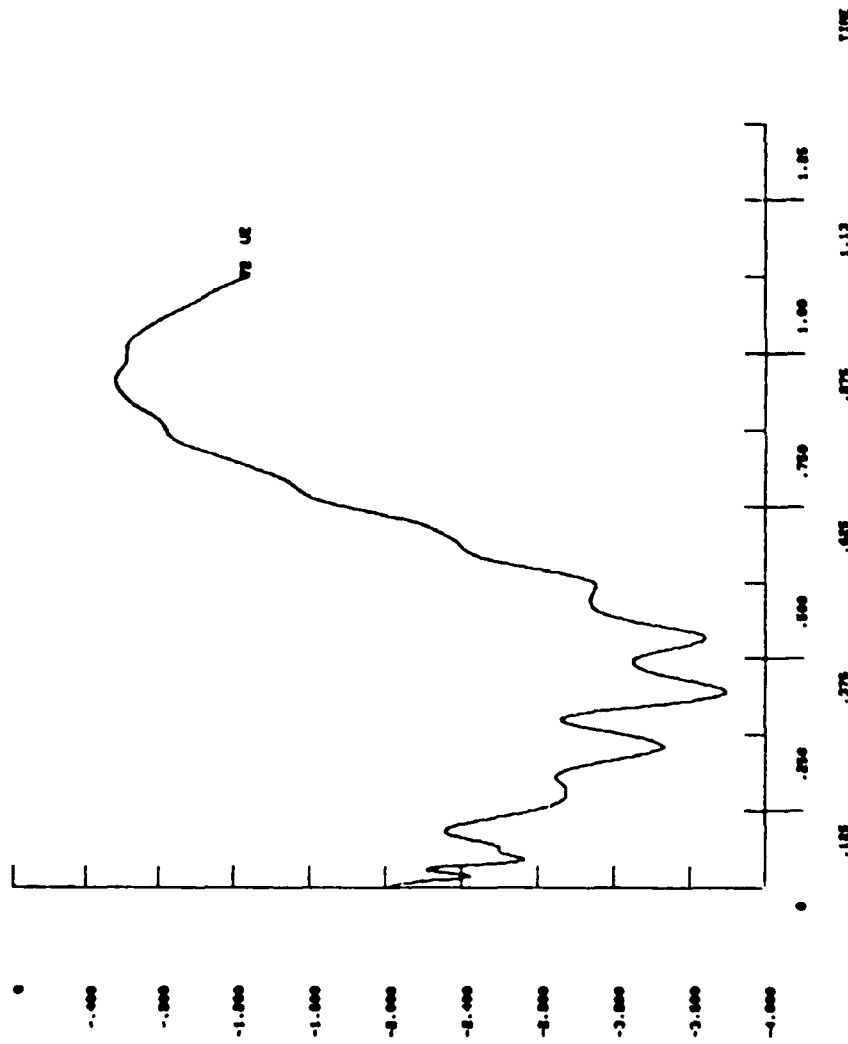
100-22.5.0 cont. C.A. 00107-011

FOI704
20-1
D157-1.43

Living with you is my dream!

| TEST TYPE | IDENTIFICATION | | SUMMARY OF MATERIALS STORED THIS STEP AND EXTREME VALUES | |
|-----------|----------------|--------|--|---------|
| | NAME | NUMBER | MINIMUM | AT TIME |
| 0 8100 | 70 | 42 | -3.703 | 0.3100 |
| 0 8100 | 70 | 42 | -0.9506 | 0.0000 |

13. Mr. William Wright 1874

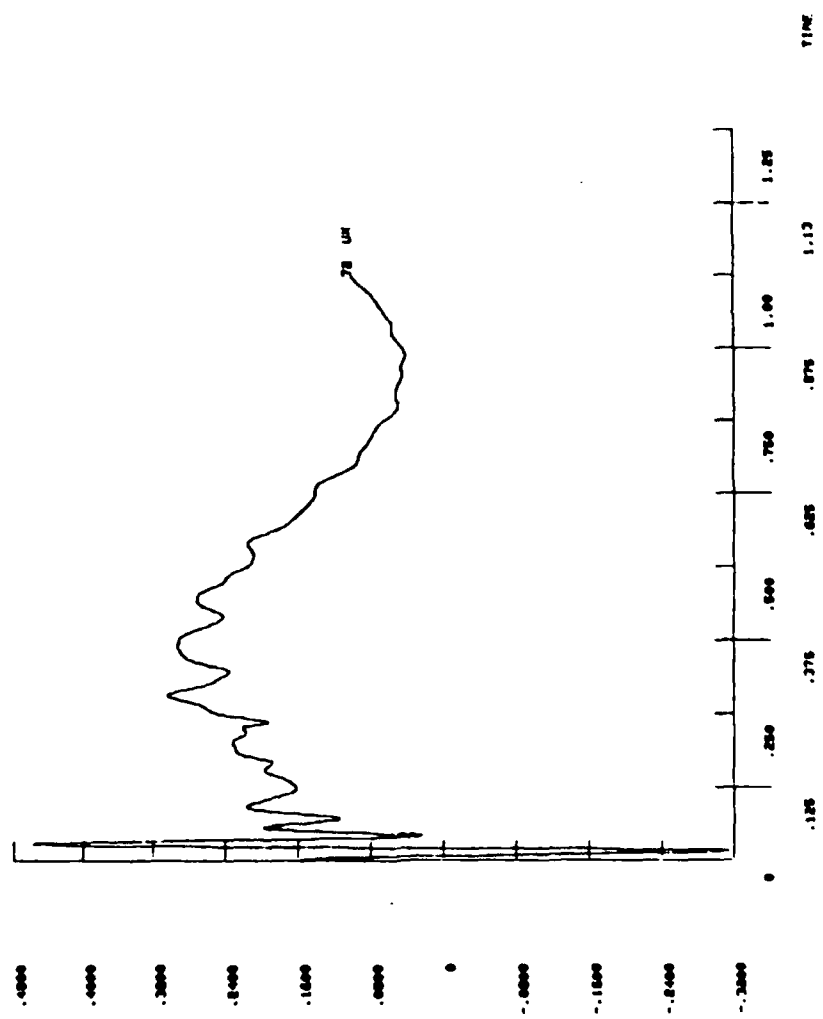


100-22,500 CAS, C.R. CONTINUED

POSTAGE
PAID
D167-1.38

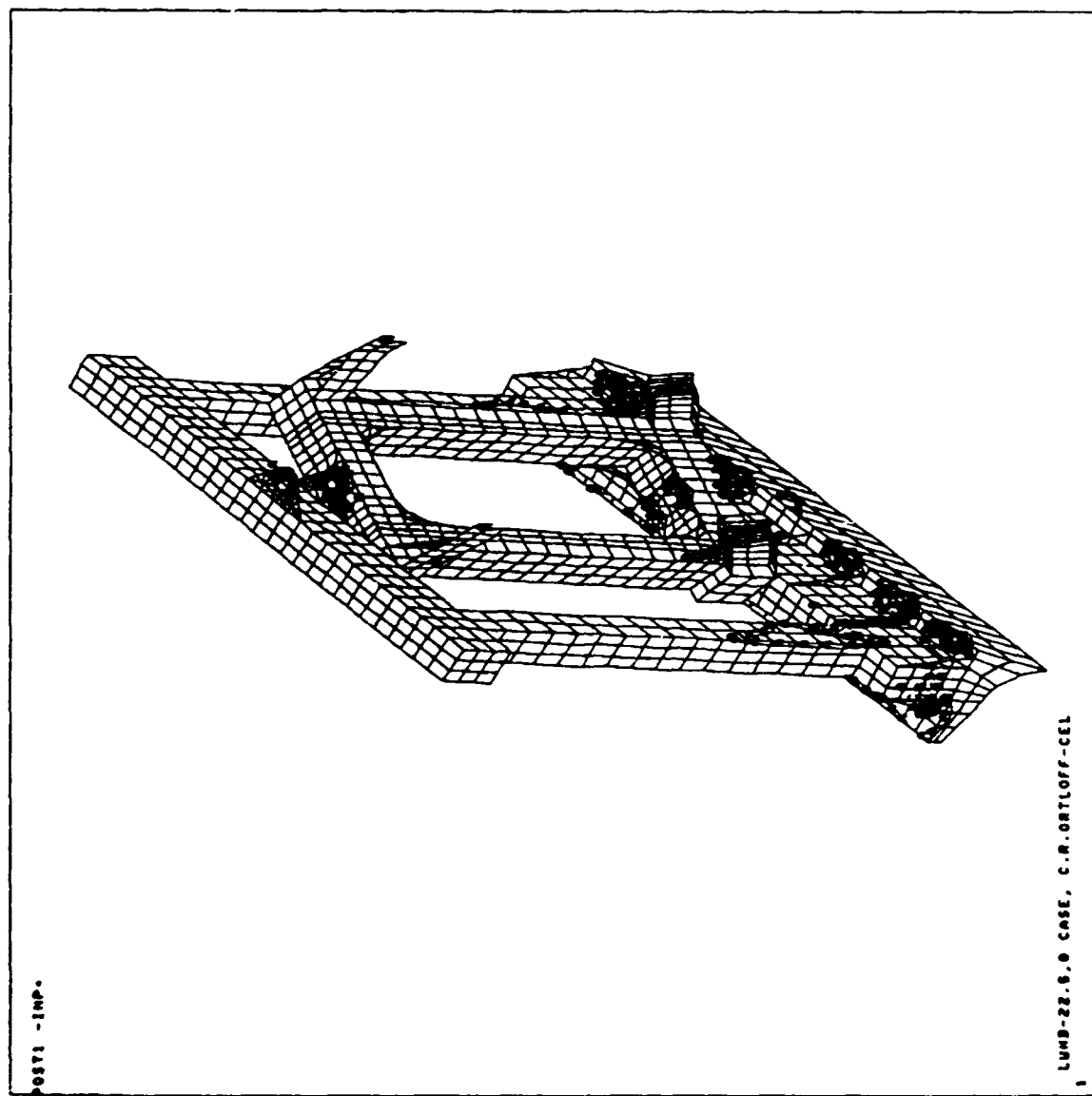
COMPLETION FOR 1001 DATA POINTS
 SUMMARY OF UNLOADED STORED THIS STEP AND EXTREME VALUES
 MAX TYPE IDENTIFIERS MADE MINIMUM AT TIME MAXIMUM AT TIME
 0 010 78 UN 78 UN -0.3132 0.16000-01 0.4576 0.00000-01
 PLT DEFINITION VALUE
 SCALE UNIT 78 UN

POST06
 20-1
 0107-1.43



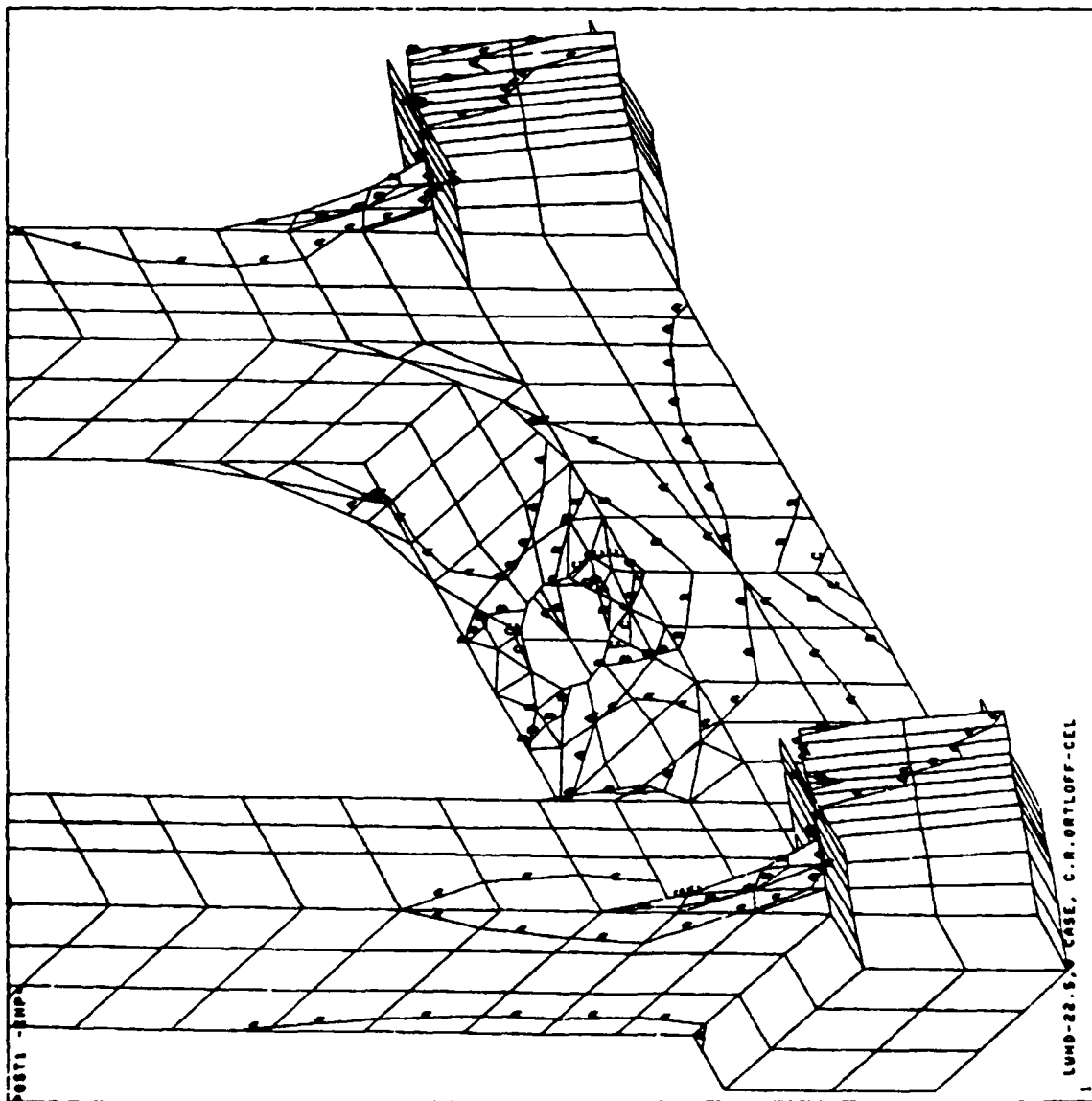
LAMP-DE 5.0 CASE, C.R. ANTILAMP-CELL

ANSYS 4.20
 JAN 5 1987
 12130114
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.318
 SLOC
 TOP
 ZOOM
 KU=1
 VU=.6
 ZU=-.6
 DIST=108
 XF=54
 VF=26.4
 ZF=5.26
 VRT0=1.71
 MIDDEN
 RX=232858
 RM=393
 A=39934
 B=77678
 C=116322
 D=154966
 E=193610



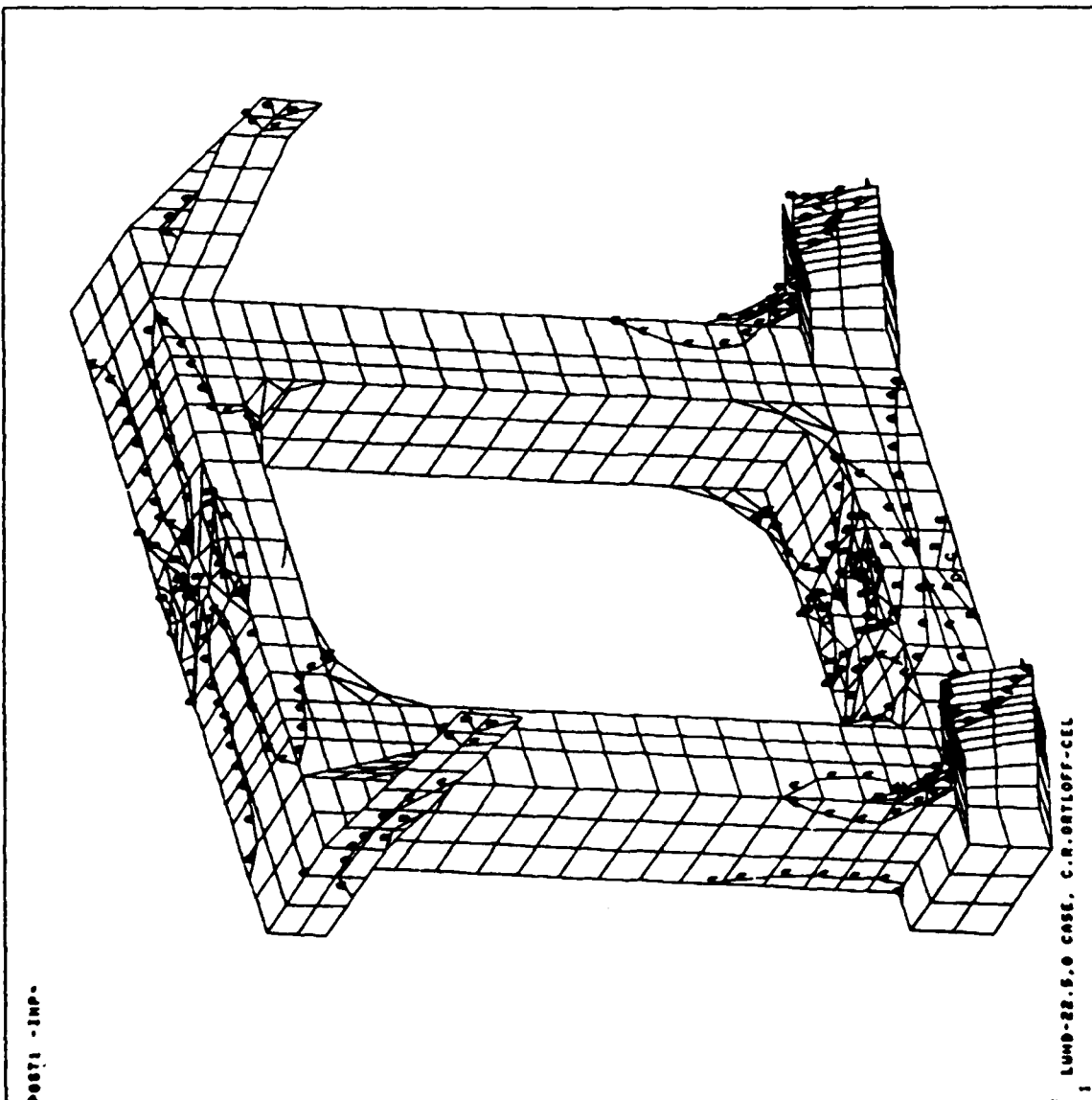
Von Mises
 Equivalent Stress

ANSYS 4.20
 JAN 6 1987
 12122137
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.318
 SICE
 TOP
 200R
 XU=1
 YU=.6
 ZU=-.6
 2 B187-28
 2 XF=61
 2 VF=20.6
 2 ZF=-12.3
 VSTD=1.71
 HIDDEN
 RX=95590
 RH=0
 A=15400
 B=32238
 C=48076
 D=63914
 E=79752

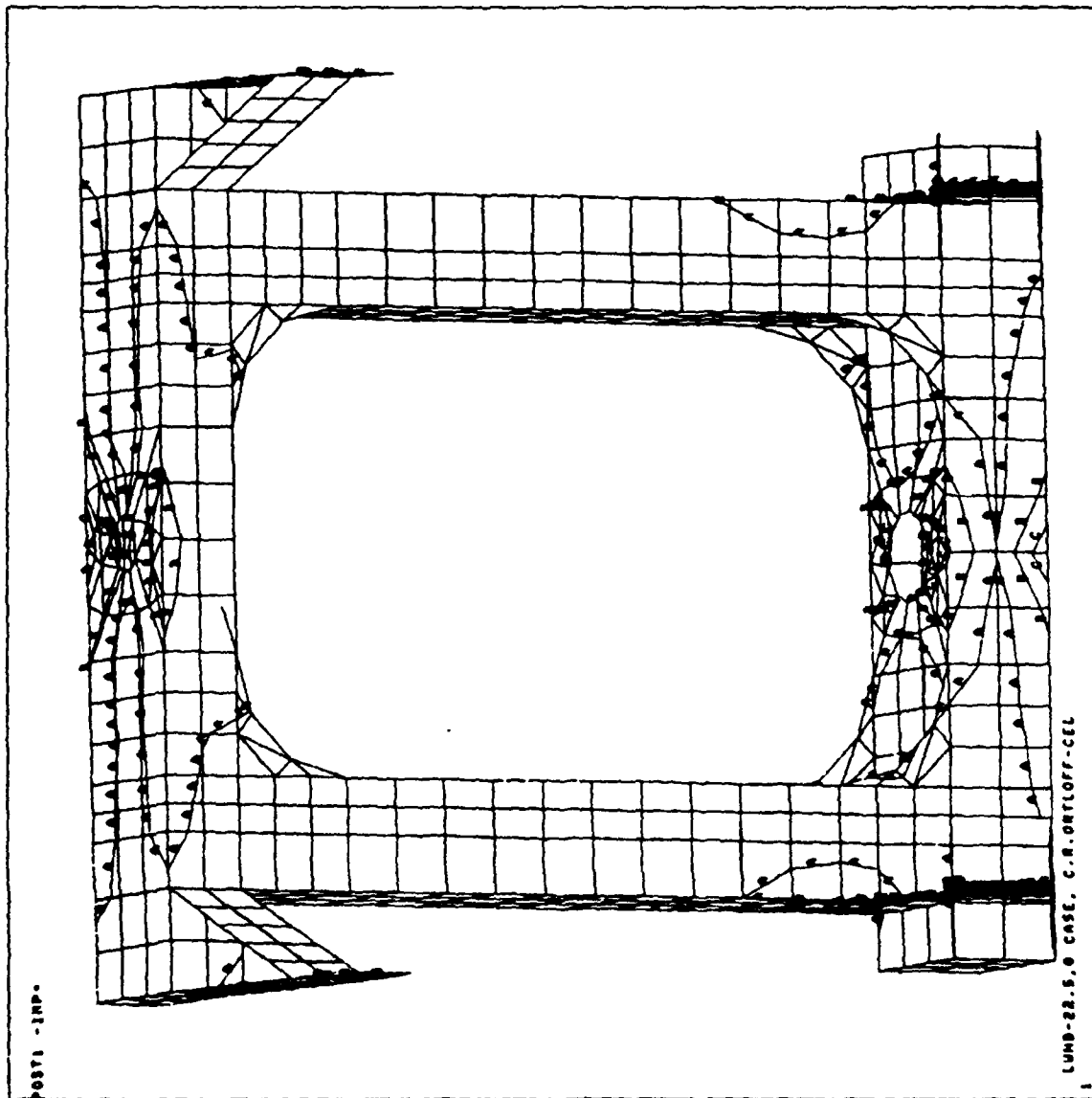


GIMBAL

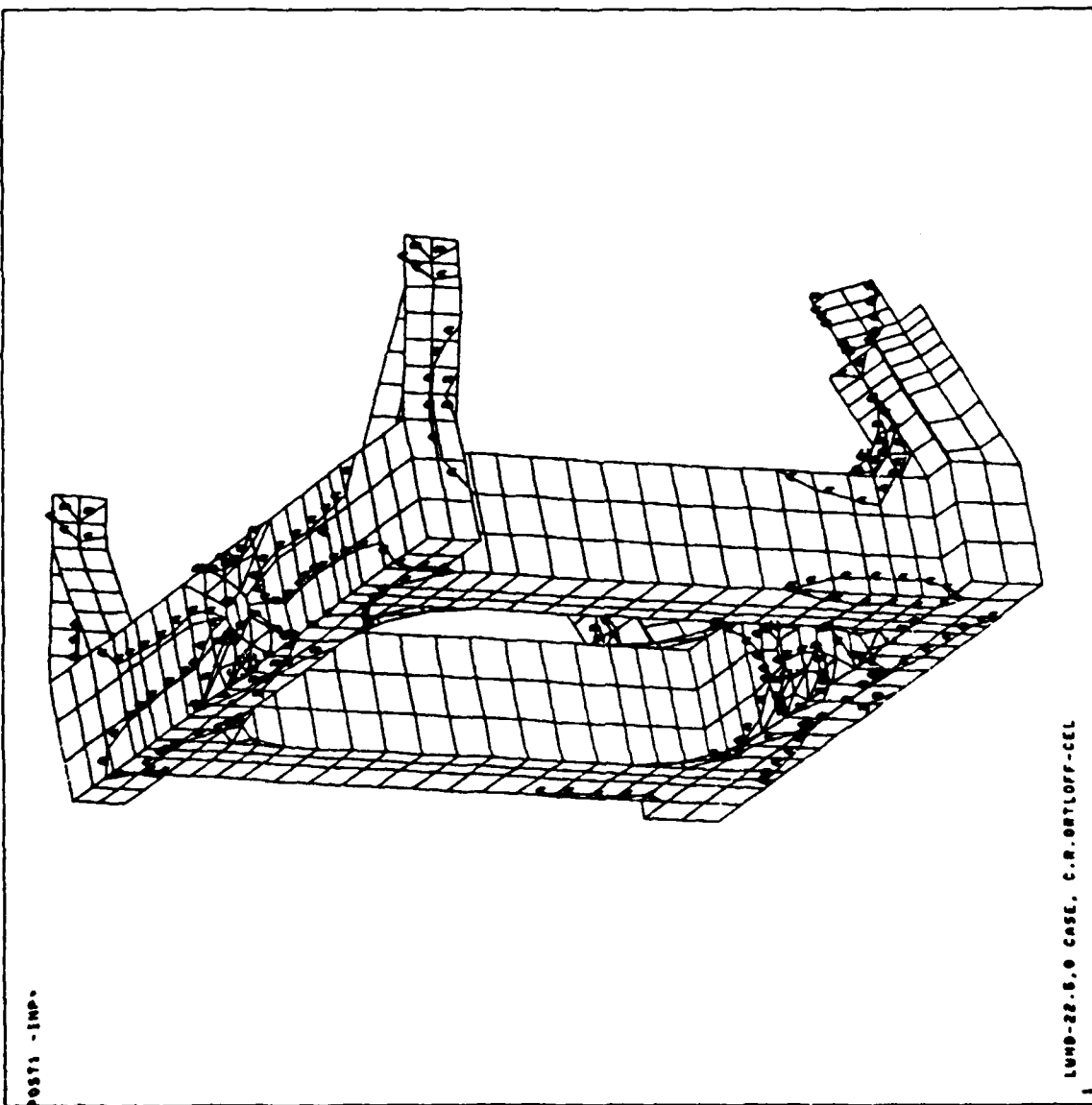
ANSYS 4.20
 JAN 5 1987
 18122137
 POST1 STRESS
 STEP=1
 1789-1
 TIME=.318
 SICE
 TOP
 XU=1
 VU=.6
 ZU=-.6
 B157=31.3
 MF=54.4
 VF=35.2
 ZF=-8.78
 M189CM
 MK=95590
 MN=563
 A=16400
 B=22238
 C=48076
 D=63914
 E=70752

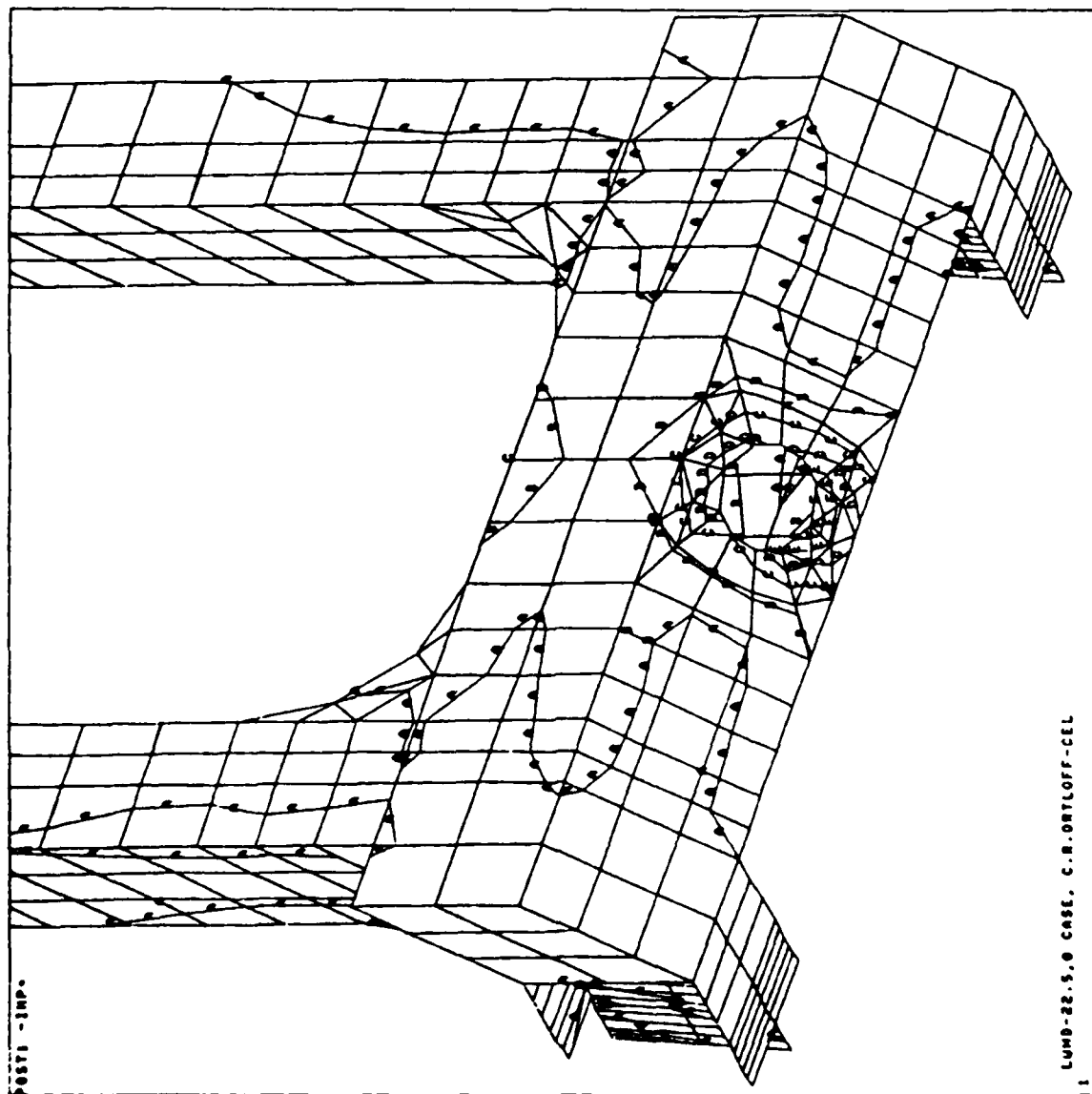


ANSYS 4.20
 JAN 5 1987
 12:19:23
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.318
 STOE
 TOP
 NU=.5
 VU=.5
 ZU=.1
 DIST=26.5
 KP=54.8
 VP=35.1
 ZP=-8.05
 MIDDLE
 MM=55590
 MM=563
 A=1600
 B=32238
 C=48076
 D=62914
 E=79752



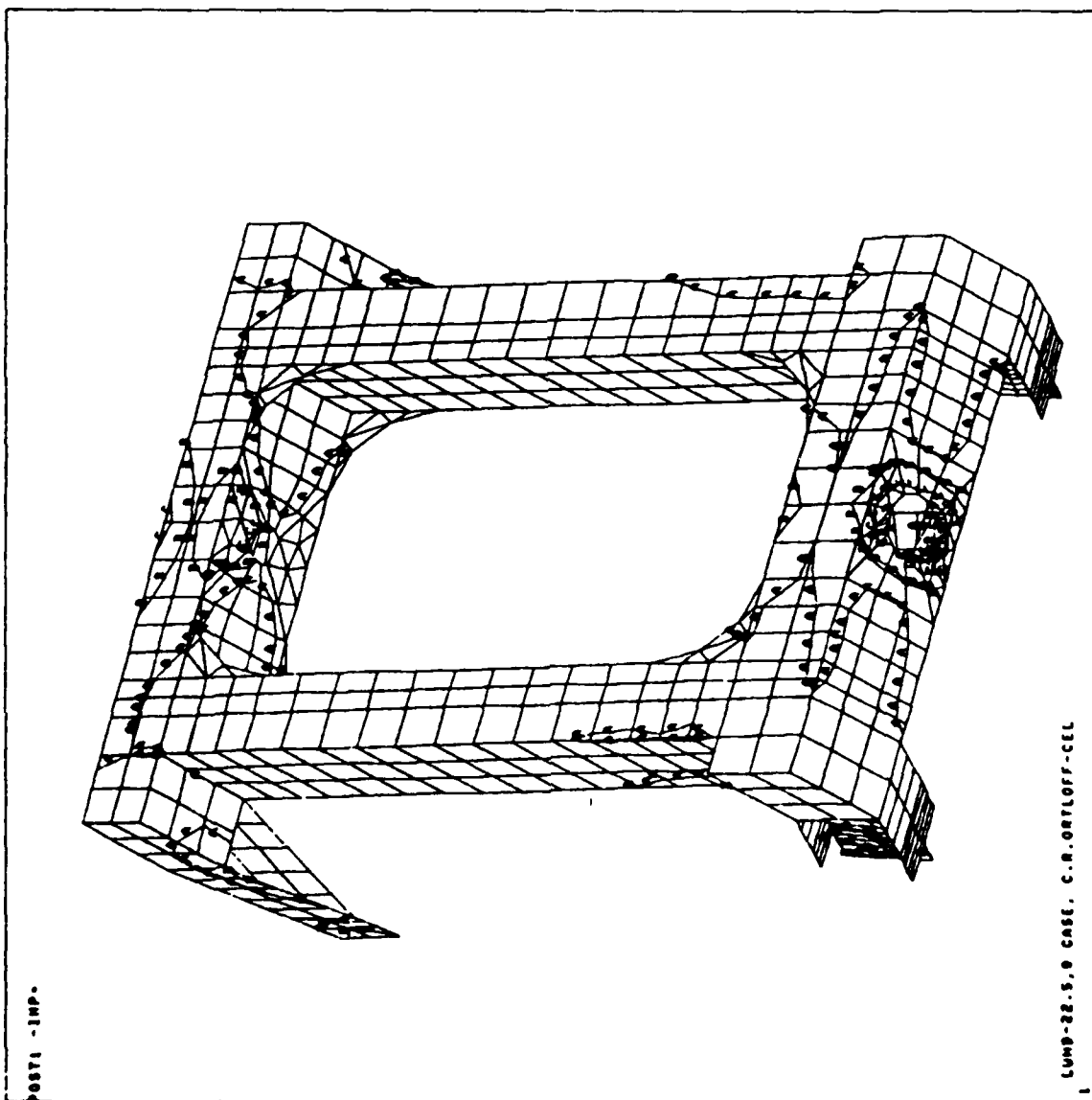
ARSYS 4.00
 JAN 5 1987
 12:18:28
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.318
 SICE
 TOP
 NU=1
 VU=1
 ZU=1
 DIST=34.8
 MF=57.3
 VF=33.9
 ZF=-7.62
 HIDDEN
 MN=95500
 MN=563
 A=10400
 D=32238
 C=48876
 D=63914
 E=70752



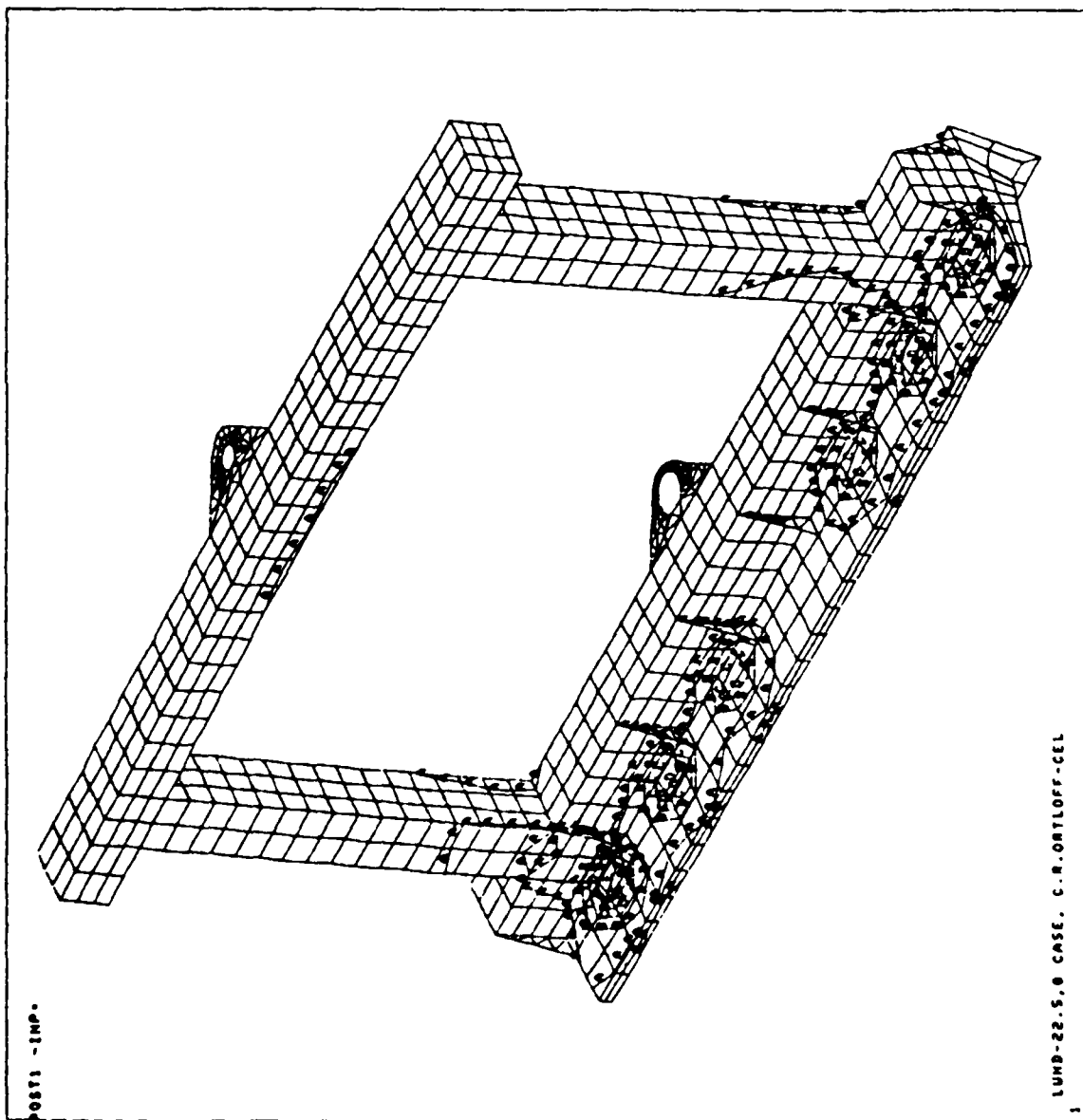


ANSYS 4.20
 JAN 5 1987
 12:05:46
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.318
 SICE
 TOP
 ZOOM
 XU=-1
 VU=-1
 ZU=1
 1 DIST=31.8
 2 RF=59.5
 3 VF=24
 4 ZF=13.4
 XRT0=1.43
 VRT0=2.18
 MIDDLE
 MX=95500
 MY=0
 A=14136
 B=27712
 C=41888
 D=54864
 E=68440
 F=82016

ANSYS 4.20
 JAN 5 1987
 12:05:46
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.318
 SIZE
 TOP
 ZOOM
 KU=-1
 YU=-1
 ZU=-1
 DIST=83.3
 MF=63.8
 VF=35
 ZF=-7.83
 XRTC 1.43
 VRT0=1.8
 HIDDEN
 M1=95590
 M1=562
 A=16400
 B=32238
 C=48076
 D=63914
 E=78752

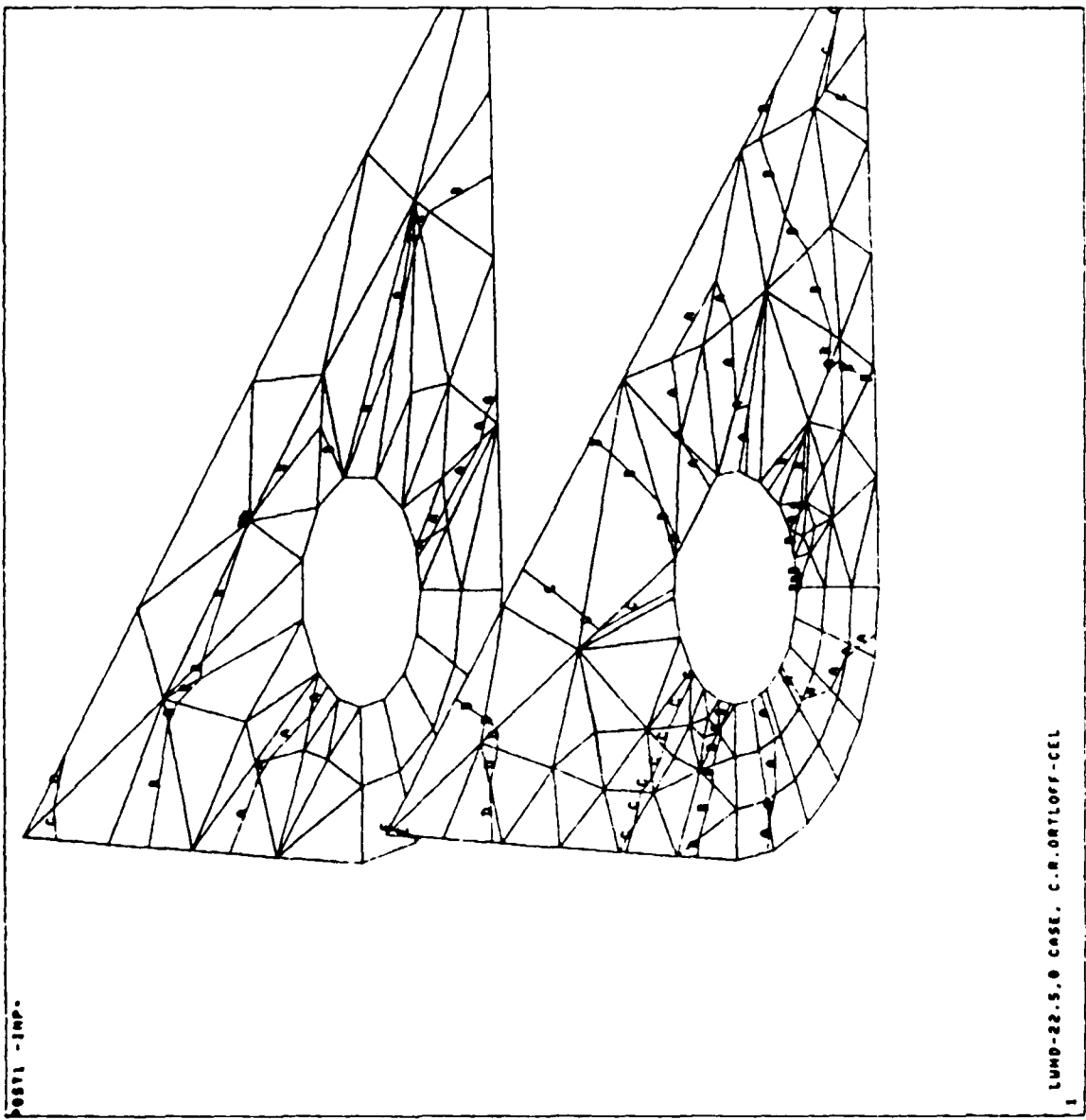


ANSYS 4.20
 JAN 5 1987
 11:41:00
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.310
 SICE
 TOP
 KU=1
 YU=1
 ZU=1
 DIST=56.6
 MF=51.2
 VF=27.7
 ZF=4.17
 MIDDEN
 MX=232252
 MY=393
 A=38934
 B=77678
 C=116322
 D=154066
 E=193610



100-225,0 CASE, C.A. DUFFY-CEL

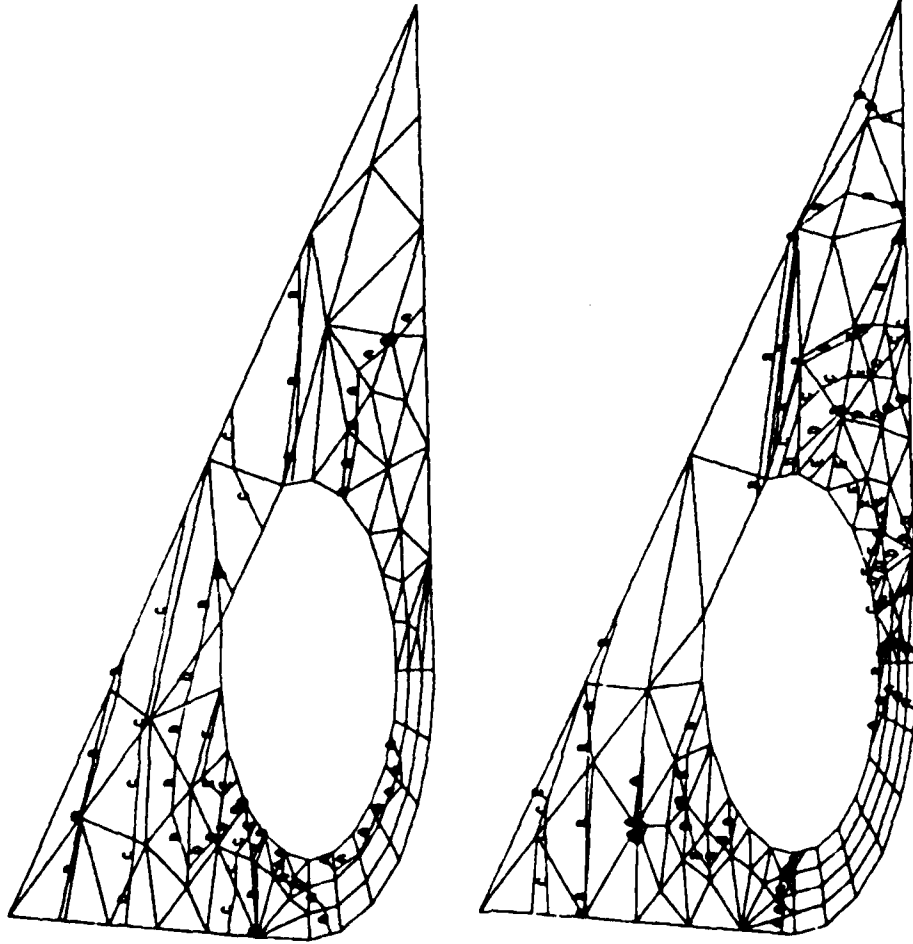
ANSYS 4.28
 JAN 5 1987
 11:51:22
 POST1 STRESS
 STEP=1
 LVER=1
 TIME=.318
 SICE
 TOP
 ZOOM
 XU=-1
 YU=-1
 ZU=-1
 S DIST=7.14
 S KF=42.4
 S VF=48.2
 S ZF=6.95
 KRT0=1.08
 M19DEM
 MX=20038
 MY=383
 A=437
 B=8482
 C=12527
 D=16572
 E=20617



POST1 -IMP.
AUTO

FOR WINDOW 1 VIEW DISTANCE, FOCUS POINT, CONTOUR SPECIFICATIONS,
AND DISTORTION SCALING AUTOMATICALLY CALCULATED

POST1 -IMP.

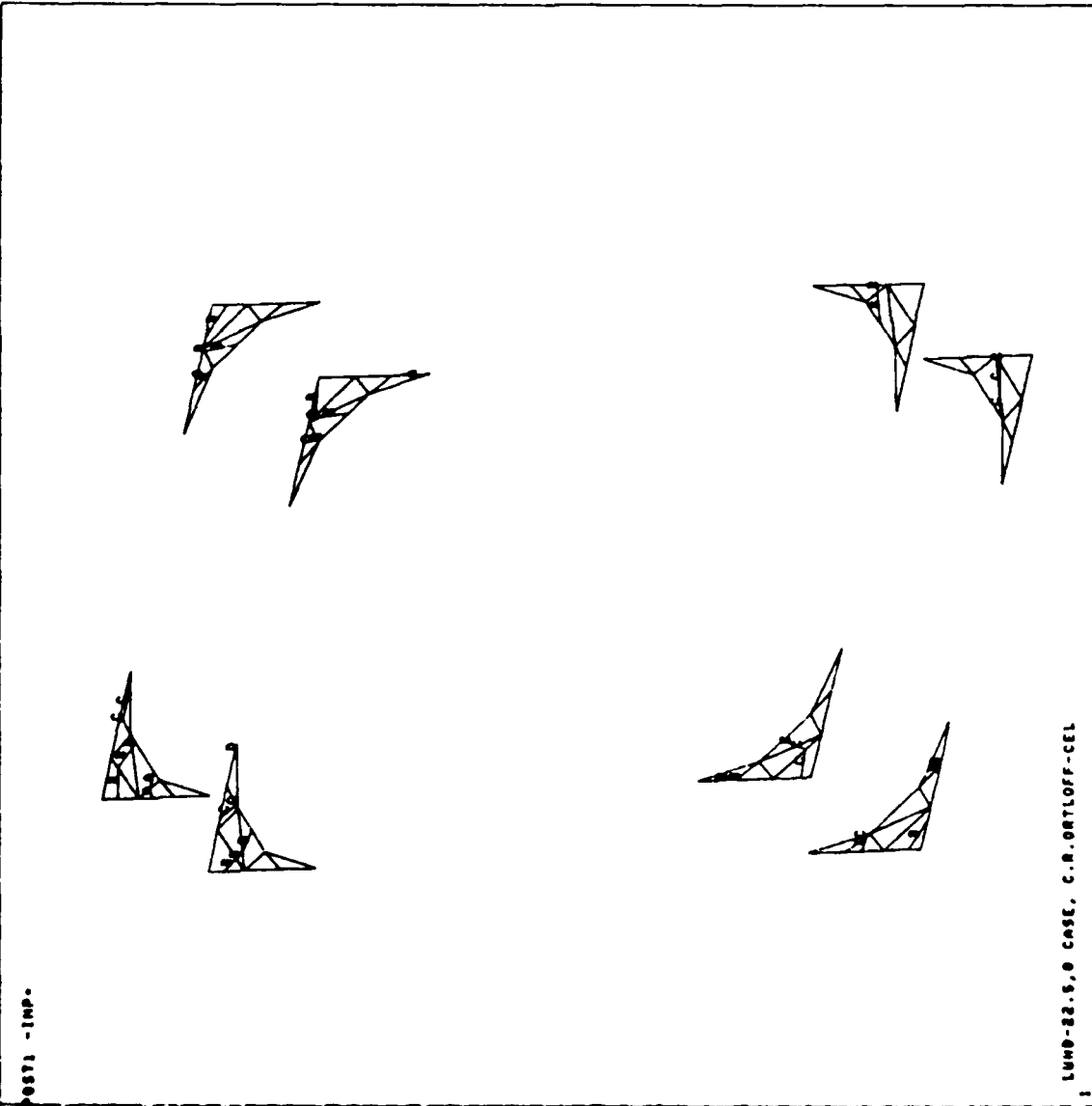


LUMB-22.5.0 CASE, C.R.ORTLOFF-CEL

ANSYS 4.20
JAN 5 1987
11:53:18
POST1 STRESS
STEP=1
ITER=1
TIME=.318
SIZE
TOP
ZOOM
XU=-1
YU=-1
ZU=1
E BIST-B.49
E MF-61.9
E VF-13.2
E ZF--8.83
XRT0-1.26
HIDDEN
NN-24661
NN-949
A-4437
B-8482
C-12527
D-16572
E-20617

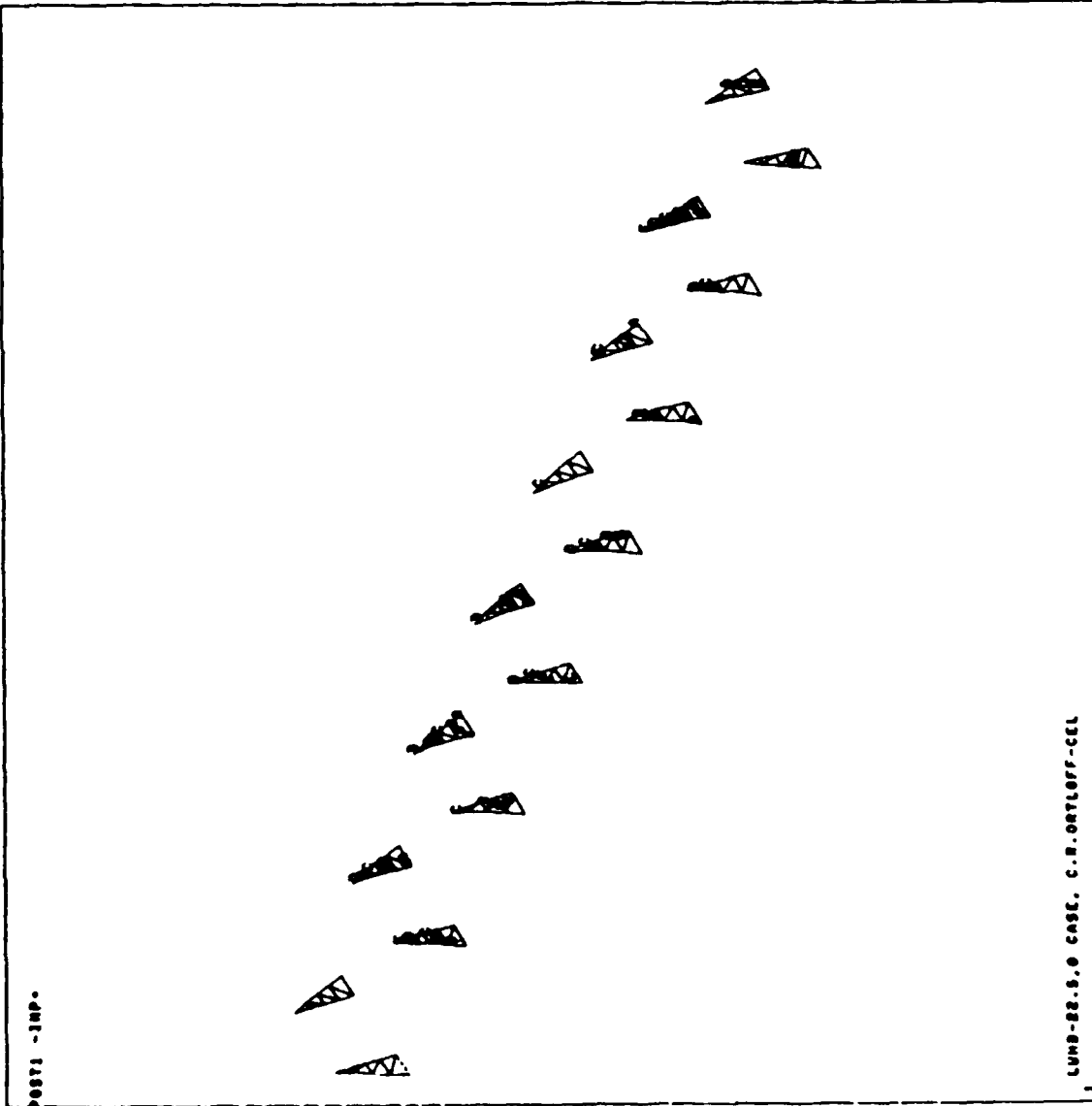
BOTTOM TABS

ANSYS 4.28
 JAN 5 1987
 13104114
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.318
 SLOC
 TOP
 NU=-1
 VU=-1
 ZU=1
 8 D167-23.7
 8 1F-53
 8 VF-33.6
 8 2F-3.5
 HIDDEN
 MX-19820
 NM-2487
 A-5328
 B-16117
 C-14895
 D-18073



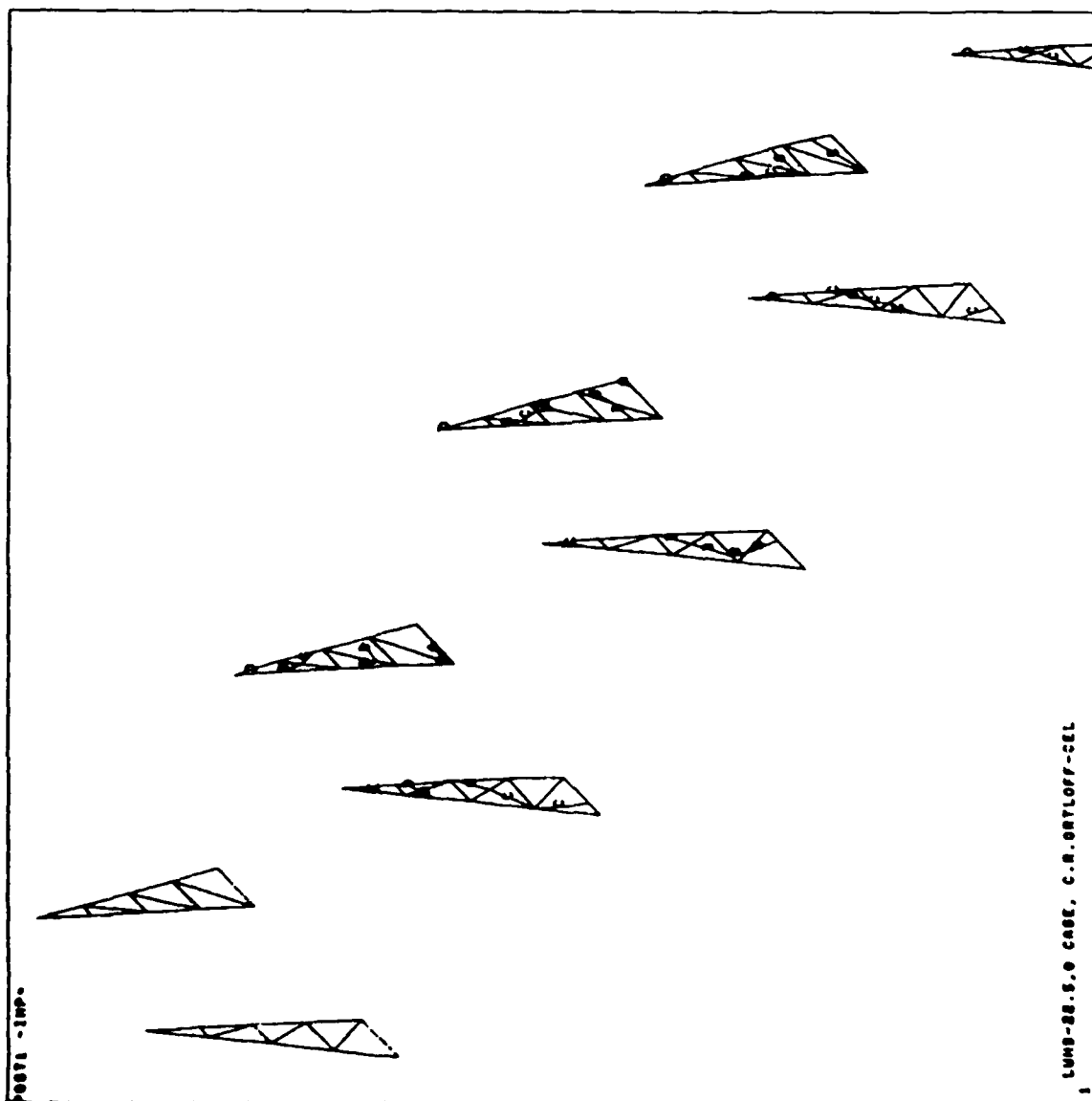
GIMBAL
 CORNER
 SUPPORTS

ARSV 4.89
 JAN 5 1987
 11:50:40
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.318
 SIG
 TOP
 ZOOM
 XU=-1
 YU=-1
 ZU=1
 DIST=57.6
 XF=82.8
 YF=3.95
 ZF=3.7
 XRT0=1.86
 HIDDEN
 RK=92444
 RW=1011
 A=10249
 B=31408
 C=46727
 D=61905
 E=77205

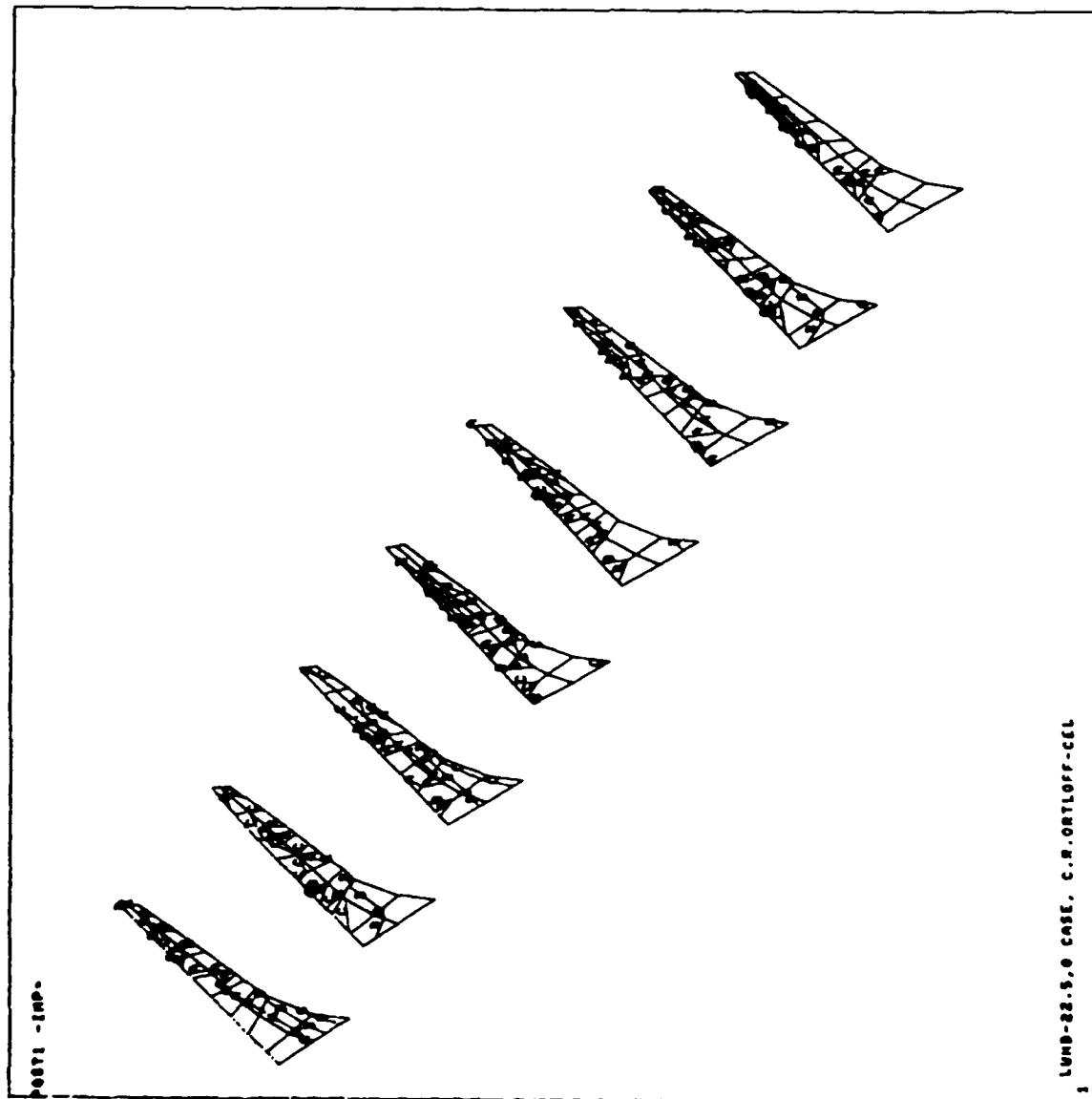


TRIANGULAR
 TAB REINFORCING-
 PLATES - PLATFORM
 LOWER BOX BEAM
 TO HORIZONTAL
 SPADE PLATE

8 D18T-30.2
 8 XF-23.9
 8 VF-12.6
 8 ZF-6.12
 8 MRT0-1.26
 8 VRT0-1.8
 8 MIDDIN
 8 MX-92444
 8 MN-1011
 8 A-10249
 8 B-21488
 8 C-46727
 8 D-61986
 8 E-77891



ANSYS 4.28
 JAN 5 1987
 18:08:34
 POST1 STRSS
 STEP=1
 ITER=1
 TIME=.318
 SICE
 TOP
 ZOOM
 XU=-1
 YU=-1
 ZU=1
 DIST=70.3
 XF=54.1
 YF=-8.93
 ZF=4.93
 MATO=1.43
 VATO=1.8
 HIDDEN
 MR=5468
 MM=4737
 A=13683
 B=21280
 C=29717
 D=38044
 E=46371

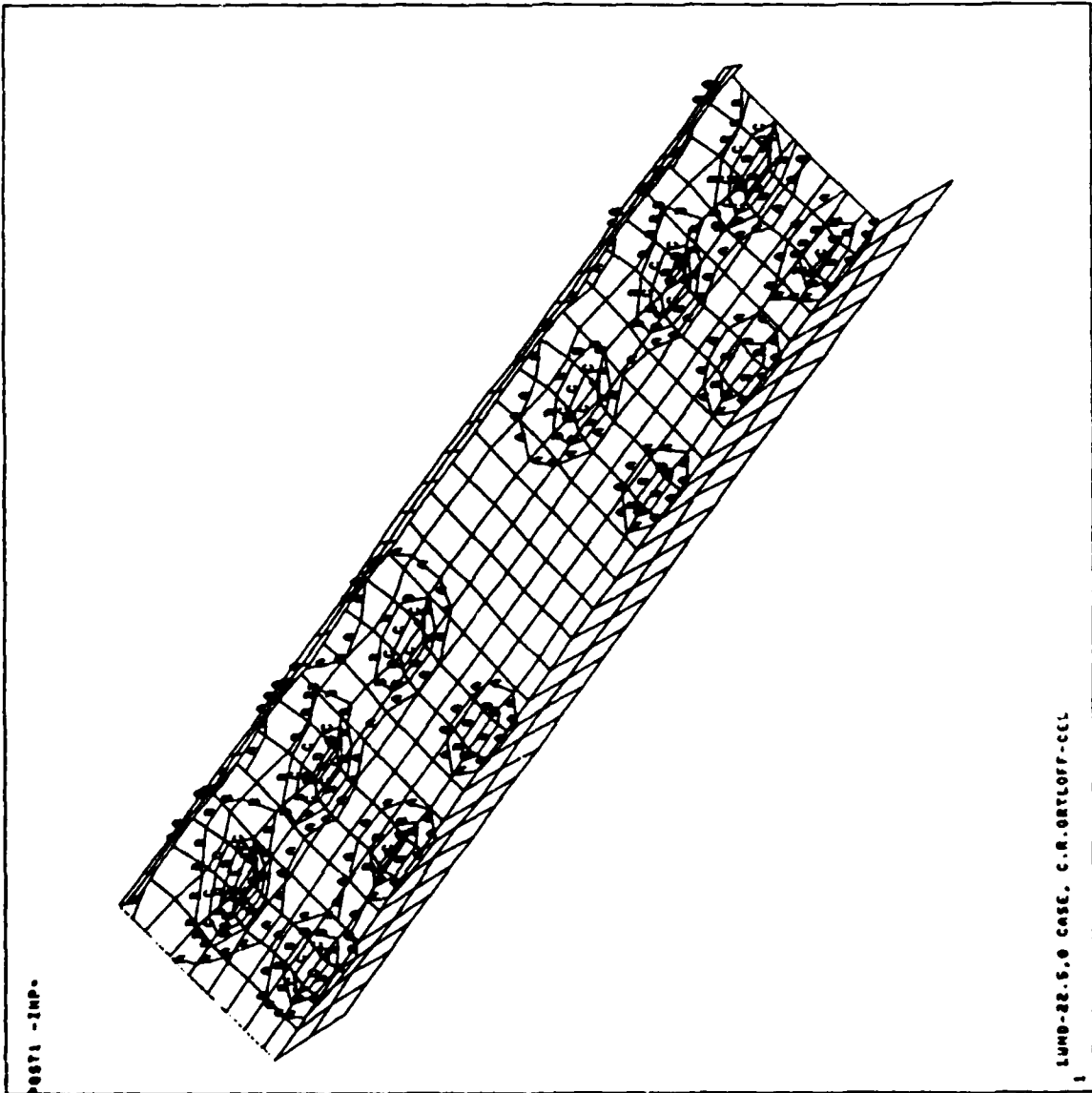


SPAD
 REINFORCING—
 PLATES

ANSYS 4.20
 JAN 5 1987
 12103146
 POST1 STRESS

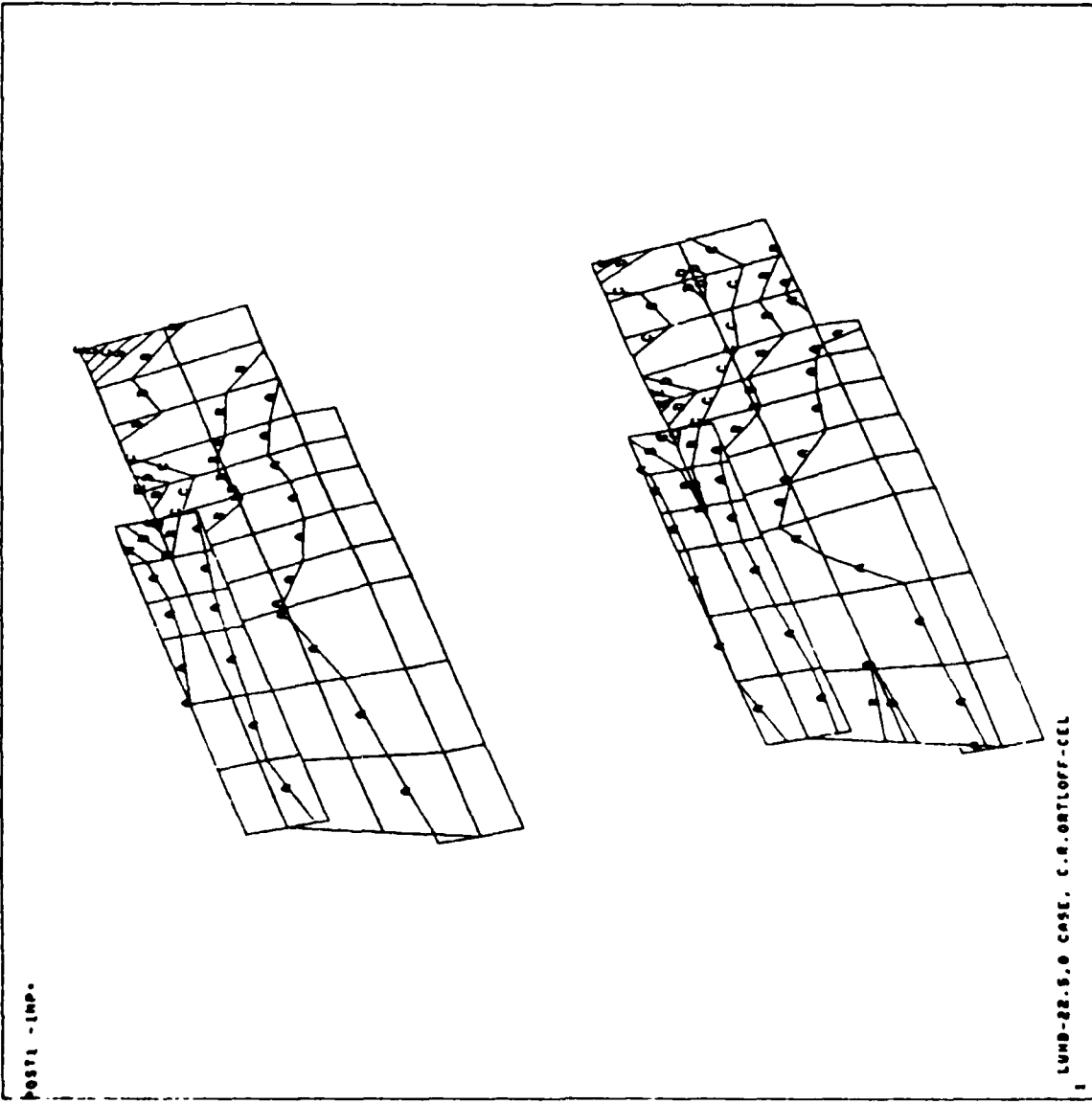
STEP=1
 ITER=1
 TIME=.310
 SLOC
 TOP

ZOOM
 KU=-1
 VU=-1
 ZU=1
 DIST=70.3
 XF=54.1
 YF=-8.83
 ZF=4.03
 XRT0=1.43
 YRT0=1.8
 MIBDEN
 RM=232852
 RM=1673
 A=40102
 B=78532
 C=116962
 D=155202
 E=193822



LOWER
 HORIZONTAL
 SPADE PLATE

ANSYS 4.20
 JAN 5 1987
 13108140
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.318
 SIZE
 TOP
 XU=1
 VU=.5
 ZU=.5
 DIST=14.2
 WF=57.1
 VF=14.1
 ZF=13.5
 MIDDLE
 RN=42400
 RM=904
 A=7821
 B=14730
 C=21657
 D=28575
 E=35493



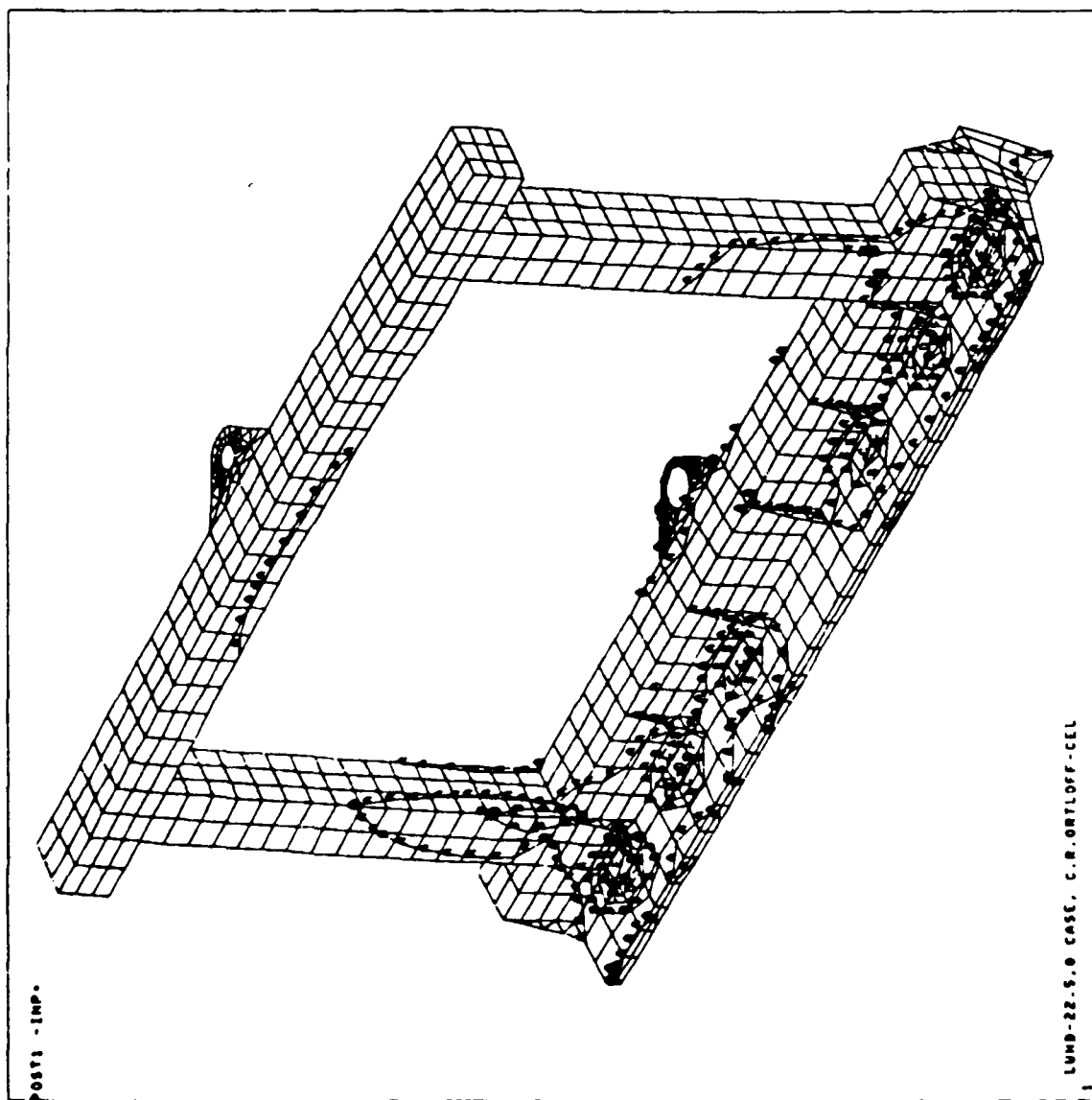
LOWER
 GIMBAL
 ARMS

LOAD STEP 1 ITERATION: 1 SECTION: 1
 TIME: 0.31000 LOAD CASE: 1

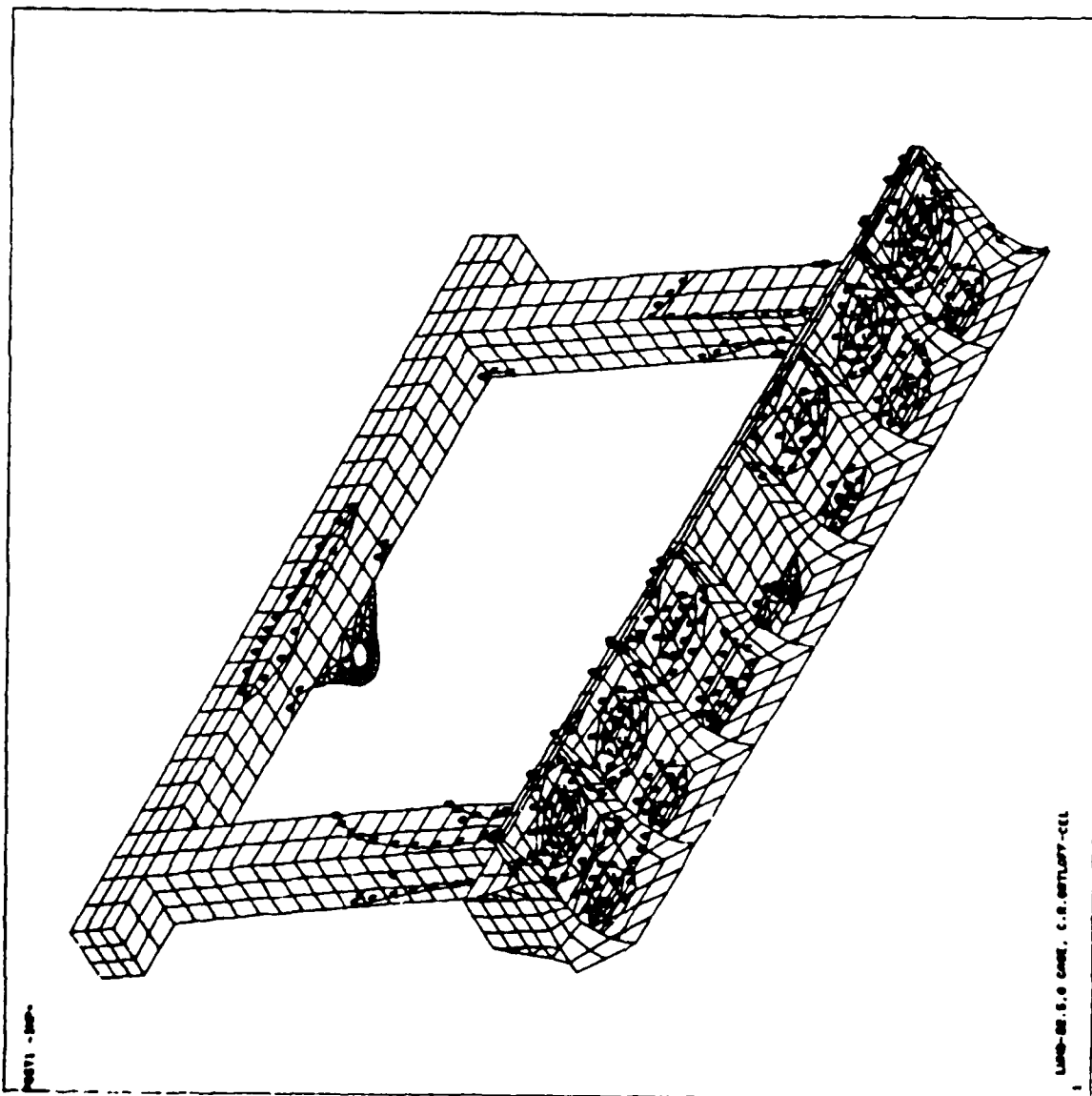
THE FOLLOWING X,Y,Z FORCES ARE IN NODAL COORDINATES

| NODE | PX | PY | PZ | MX | MY | MZ |
|------|-------|----|----|----|----|----|
| 1000 | 000.0 | | | | | |
| 1001 | 000.0 | | | | | |
| 1002 | 000.0 | | | | | |
| 1003 | 000.0 | | | | | |
| 1004 | 000.0 | | | | | |
| 1005 | 000.0 | | | | | |
| 1006 | 000.0 | | | | | |
| 1007 | 000.0 | | | | | |
| 1008 | 000.0 | | | | | |
| 1009 | 000.0 | | | | | |
| 1010 | 000.0 | | | | | |
| 1011 | 000.0 | | | | | |
| 1012 | 000.0 | | | | | |
| 1013 | 000.0 | | | | | |
| 1014 | 000.0 | | | | | |
| 1015 | 000.0 | | | | | |
| 1016 | 000.0 | | | | | |
| 1017 | 000.0 | | | | | |
| 1018 | 000.0 | | | | | |
| 1019 | 000.0 | | | | | |
| 1020 | 000.0 | | | | | |
| 1021 | 000.0 | | | | | |
| 1022 | 000.0 | | | | | |
| 1023 | 000.0 | | | | | |
| 1024 | 000.0 | | | | | |
| 1025 | 000.0 | | | | | |
| 1026 | 000.0 | | | | | |
| 1027 | 000.0 | | | | | |
| 1028 | 000.0 | | | | | |
| 1029 | 000.0 | | | | | |
| 1030 | 000.0 | | | | | |
| 1031 | 000.0 | | | | | |
| 1032 | 000.0 | | | | | |
| 1033 | 000.0 | | | | | |
| 1034 | 000.0 | | | | | |
| 1035 | 000.0 | | | | | |
| 1036 | 000.0 | | | | | |
| 1037 | 000.0 | | | | | |
| 1038 | 000.0 | | | | | |
| 1039 | 000.0 | | | | | |
| 1040 | 000.0 | | | | | |
| 1041 | 000.0 | | | | | |
| 1042 | 000.0 | | | | | |
| 1043 | 000.0 | | | | | |
| 1044 | 000.0 | | | | | |
| 1045 | 000.0 | | | | | |
| 1046 | 000.0 | | | | | |
| 1047 | 000.0 | | | | | |
| 1048 | 000.0 | | | | | |
| 1049 | 000.0 | | | | | |
| 1050 | 000.0 | | | | | |
| 1051 | 000.0 | | | | | |
| 1052 | 000.0 | | | | | |
| 1053 | 000.0 | | | | | |
| 1054 | 000.0 | | | | | |
| 1055 | 000.0 | | | | | |
| 1056 | 000.0 | | | | | |
| 1057 | 000.0 | | | | | |
| 1058 | 000.0 | | | | | |
| 1059 | 000.0 | | | | | |
| 1060 | 000.0 | | | | | |
| 1061 | 000.0 | | | | | |
| 1062 | 000.0 | | | | | |
| 1063 | 000.0 | | | | | |
| 1064 | 000.0 | | | | | |
| 1065 | 000.0 | | | | | |
| 1066 | 000.0 | | | | | |
| 1067 | 000.0 | | | | | |
| 1068 | 000.0 | | | | | |
| 1069 | 000.0 | | | | | |
| 1070 | 000.0 | | | | | |
| 1071 | 000.0 | | | | | |
| 1072 | 000.0 | | | | | |
| 1073 | 000.0 | | | | | |
| 1074 | 000.0 | | | | | |
| 1075 | 000.0 | | | | | |
| 1076 | 000.0 | | | | | |
| 1077 | 000.0 | | | | | |
| 1078 | 000.0 | | | | | |
| 1079 | 000.0 | | | | | |
| 1080 | 000.0 | | | | | |
| 1081 | 000.0 | | | | | |
| 1082 | 000.0 | | | | | |
| 1083 | 000.0 | | | | | |
| 1084 | 000.0 | | | | | |
| 1085 | 000.0 | | | | | |
| 1086 | 000.0 | | | | | |
| 1087 | 000.0 | | | | | |
| 1088 | 000.0 | | | | | |
| 1089 | 000.0 | | | | | |
| 1090 | 000.0 | | | | | |
| 1091 | 000.0 | | | | | |
| 1092 | 000.0 | | | | | |
| 1093 | 000.0 | | | | | |
| 1094 | 000.0 | | | | | |
| 1095 | 000.0 | | | | | |
| 1096 | 000.0 | | | | | |
| 1097 | 000.0 | | | | | |
| 1098 | 000.0 | | | | | |
| 1099 | 000.0 | | | | | |
| 1100 | 000.0 | | | | | |
| 1101 | 000.0 | | | | | |
| 1102 | 000.0 | | | | | |
| 1103 | 000.0 | | | | | |
| 1104 | 000.0 | | | | | |
| 1105 | 000.0 | | | | | |
| 1106 | 000.0 | | | | | |
| 1107 | 000.0 | | | | | |
| 1108 | 000.0 | | | | | |
| 1109 | 000.0 | | | | | |
| 1110 | 000.0 | | | | | |
| 1111 | 000.0 | | | | | |
| 1112 | 000.0 | | | | | |
| 1113 | 000.0 | | | | | |
| 1114 | 000.0 | | | | | |
| 1115 | 000.0 | | | | | |
| 1116 | 000.0 | | | | | |
| 1117 | 000.0 | | | | | |
| 1118 | 000.0 | | | | | |
| 1119 | 000.0 | | | | | |
| 1120 | 000.0 | | | | | |
| 1121 | 000.0 | | | | | |
| 1122 | 000.0 | | | | | |
| 1123 | 000.0 | | | | | |
| 1124 | 000.0 | | | | | |
| 1125 | 000.0 | | | | | |
| 1126 | 000.0 | | | | | |
| 1127 | 000.0 | | | | | |
| 1128 | 000.0 | | | | | |
| 1129 | 000.0 | | | | | |
| 1130 | 000.0 | | | | | |
| 1131 | 000.0 | | | | | |
| 1132 | 000.0 | | | | | |
| 1133 | 000.0 | | | | | |
| 1134 | 000.0 | | | | | |
| 1135 | 000.0 | | | | | |
| 1136 | 000.0 | | | | | |
| 1137 | 000.0 | | | | | |
| 1138 | 000.0 | | | | | |
| 1139 | 000.0 | | | | | |
| 1140 | 000.0 | | | | | |
| 1141 | 000.0 | | | | | |
| 1142 | 000.0 | | | | | |
| 1143 | 000.0 | | | | | |
| 1144 | 000.0 | | | | | |
| 1145 | 000.0 | | | | | |
| 1146 | 000.0 | | | | | |
| 1147 | 000.0 | | | | | |
| 1148 | 000.0 | | | | | |
| 1149 | 000.0 | | | | | |
| 1150 | 000.0 | | | | | |
| 1151 | 000.0 | | | | | |
| 1152 | 000.0 | | | | | |
| 1153 | 000.0 | | | | | |
| 1154 | 000.0 | | | | | |
| 1155 | 000.0 | | | | | |
| 1156 | 000.0 | | | | | |
| 1157 | 000.0 | | | | | |
| 1158 | 000.0 | | | | | |
| 1159 | 000.0 | | | | | |
| 1160 | 000.0 | | | | | |
| 1161 | 000.0 | | | | | |
| 1162 | 000.0 | | | | | |
| 1163 | 000.0 | | | | | |
| 1164 | 000.0 | | | | | |
| 1165 | 000.0 | | | | | |
| 1166 | 000.0 | | | | | |
| 1167 | 000.0 | | | | | |
| 1168 | 000.0 | | | | | |
| 1169 | 000.0 | | | | | |
| 1170 | 000.0 | | | | | |
| 1171 | 000.0 | | | | | |
| 1172 | 000.0 | | | | | |
| 1173 | 000.0 | | | | | |
| 1174 | 000.0 | | | | | |
| 1175 | 000.0 | | | | | |
| 1176 | 000.0 | | | | | |
| 1177 | 000.0 | | | | | |
| 1178 | 000.0 | | | | | |
| 1179 | 000.0 | | | | | |
| 1180 | 000.0 | | | | | |
| 1181 | 000.0 | | | | | |
| 1182 | 000.0 | | | | | |
| 1183 | 000.0 | | | | | |
| 1184 | 000.0 | | | | | |
| 1185 | 000.0 | | | | | |
| 1186 | 000.0 | | | | | |
| 1187 | 000.0 | | | | | |
| 1188 | 000.0 | | | | | |
| 1189 | 000.0 | | | | | |
| 1190 | 000.0 | | | | | |
| 1191 | 000.0 | | | | | |
| 1192 | 000.0 | | | | | |
| 1193 | 000.0 | | | | | |
| 1194 | 000.0 | | | | | |
| 1195 | 000.0 | | | | | |
| 1196 | 000.0 | | | | | |
| 1197 | 000.0 | | | | | |
| 1198 | 000.0 | | | | | |
| 1199 | 000.0 | | | | | |
| 1200 | 000.0 | | | | | |
| 1201 | 000.0 | | | | | |
| 1202 | 000.0 | | | | | |
| 1203 | 000.0 | | | | | |
| 1204 | 000.0 | | | | | |
| 1205 | 000.0 | | | | | |
| 1206 | 000.0 | | | | | |
| 1207 | 000.0 | | | | | |
| 1208 | 000.0 | | | | | |
| 1209 | 000.0 | | | | | |
| 1210 | 000.0 | | | | | |
| 1211 | 000.0 | | | | | |
| 1212 | 000.0 | | | | | |
| 1213 | 000.0 | | | | | |
| 1214 | 000.0 | | | | | |
| 1215 | 000.0 | | | | | |
| 1216 | 000.0 | | | | | |
| 1217 | 000.0 | | | | | |
| 1218 | 000.0 | | | | | |
| 1219 | 000.0 | | | | | |
| 1220 | 000.0 | | | | | |
| 1221 | 000.0 | | | | | |
| 1222 | 000.0 | | | | | |
| 1223 | 000.0 | | | | | |
| 1224 | 000.0 | | | | | |
| 1225 | 000.0 | | | | | |
| 1226 | 000.0 | | | | | |
| 1227 | 000.0 | | | | | |
| 1228 | 000.0 | | | | | |
| 1229 | 000.0 | | | | | |
| 1230 | 000.0 | | | | | |
| 1231 | 000.0 | | | | | |
| 1232 | 000.0 | | | | | |
| 1233 | 000.0 | | | | | |
| 1234 | 000.0 | | | | | |
| 1235 | 000.0 | | | | | |
| 1236 | 000.0 | | | | | |
| 1237 | 000.0 | | | | | |
| 1238 | 000.0 | | | | | |
| 1239 | 000.0 | | | | | |
| 1240 | 000.0 | | | | | |
| 1241 | 000.0 | | | | | |
| 1242 | 000.0 | | | | | |
| 1243 | 000.0 | | | | | |
| 1244 | 000.0 | | | | | |
| 1245 | 000.0 | | | | | |
| 1246 | 000.0 | | | | | |
| 1247 | 000.0 | | | | | |
| 1248 | 000.0 | | | | | |
| 1249 | 000.0 | | | | | |
| 1250 | 000.0 | | | | | |
| 1251 | 000.0 | | | | | |
| 1252 | 000.0 | | | | | |
| 1253 | 000.0 | | | | | |
| 1254 | 000.0 | | | | | |
| 1255 | 000.0 | | | | | |
| 1256 | 000.0 | | | | | |
| 1257 | 000.0 | | | | | |
| 1258 | 000.0 | | | | | |
| 1259 | 000.0 | | | | | |
| 1260 | 000.0 | | | | | |
| 1261 | 000.0 | | | | | |
| 1262 | 000.0 | | | | | |
| 1263 | 000.0 | | | | | |
| 1264 | 000.0 | | | | | |
| 1265 | 000.0 | | | | | |
| 1266 | 000.0 | | | | | |
| 1267 | 000.0 | | | | | |
| 1268 | 000.0 | | | | | |
| 1269 | 000.0 | | | | | |
| 1270 | 000.0 | | | | | |
| 1271 | 000.0 | | | | | |
| 1272 | 000.0 | | | | | |
| 1273 | 000.0 | | | | | |
| 1274 | 000.0 | | | | | |
| 1275 | 000.0 | | | | | |
| 1276 | 000.0 | | | | | </ |

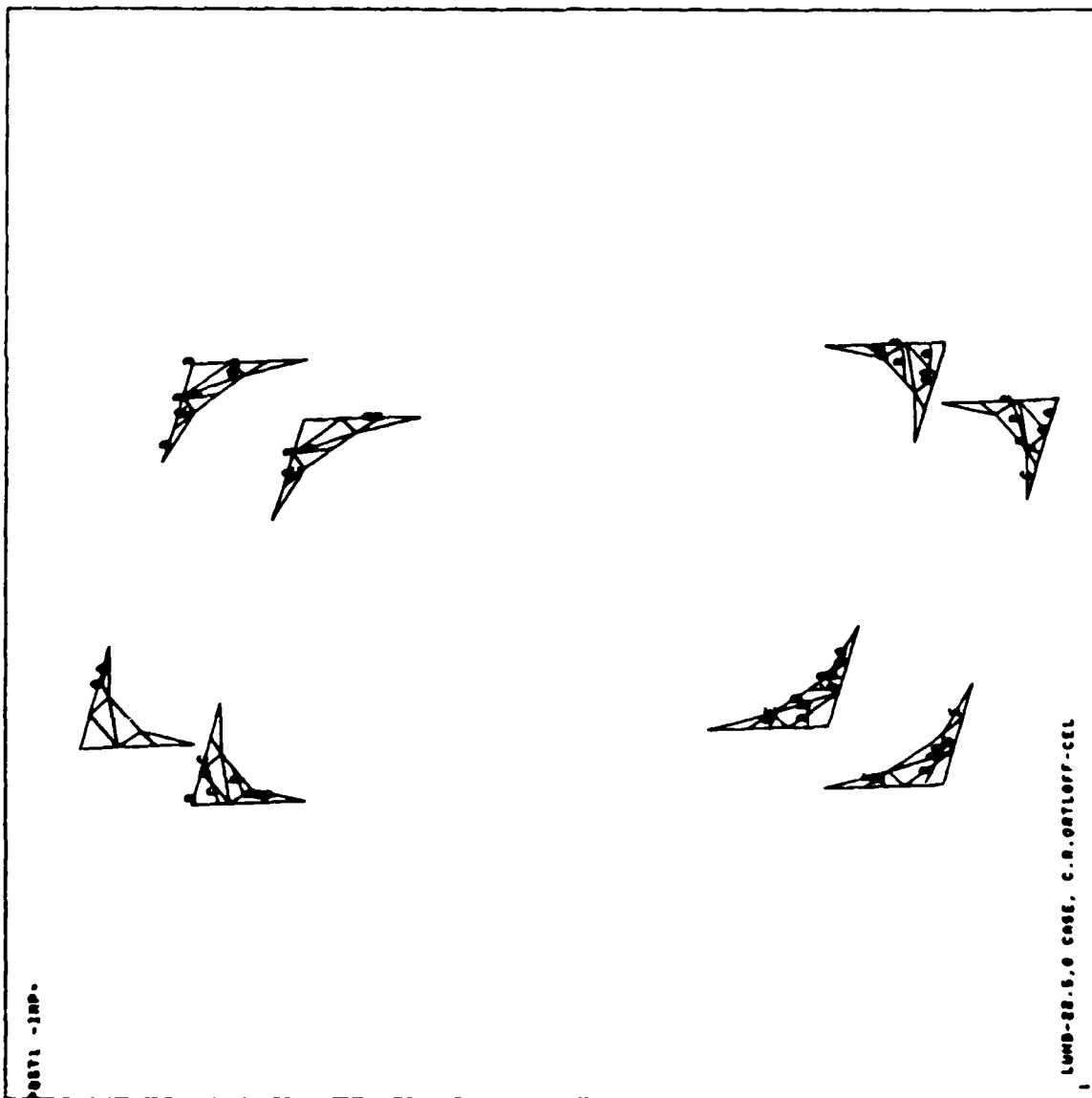
ANSYS 4.20
 JAN 6 1987
 9:47:20
 POST1 STRESS
 STEP=1
 LTR=1
 TIME=.018
 SICE
 TOP
 KU=1
 VU=1
 ZU=1
 DIST=56.6
 XF=51.2
 YF=27.7
 ZF=4.17
 HIDDEN
 RK=127580
 RM=605
 A=21267
 B=42930
 C=64083
 D=95256
 E=106419



00010 4.20
 JAN 6 1987
 01-20-13
 00071 070000
 STEP-1
 STEP-1
 TIME-0.010
 SIZE
 TOP
 00-1
 00-1
 00-1
 0107-00.0
 07-04.0
 07-00.4
 07-04.00
 010000
 00-107000
 00-000
 0-01007
 0-00000
 0-00000
 0-00000
 0-00000

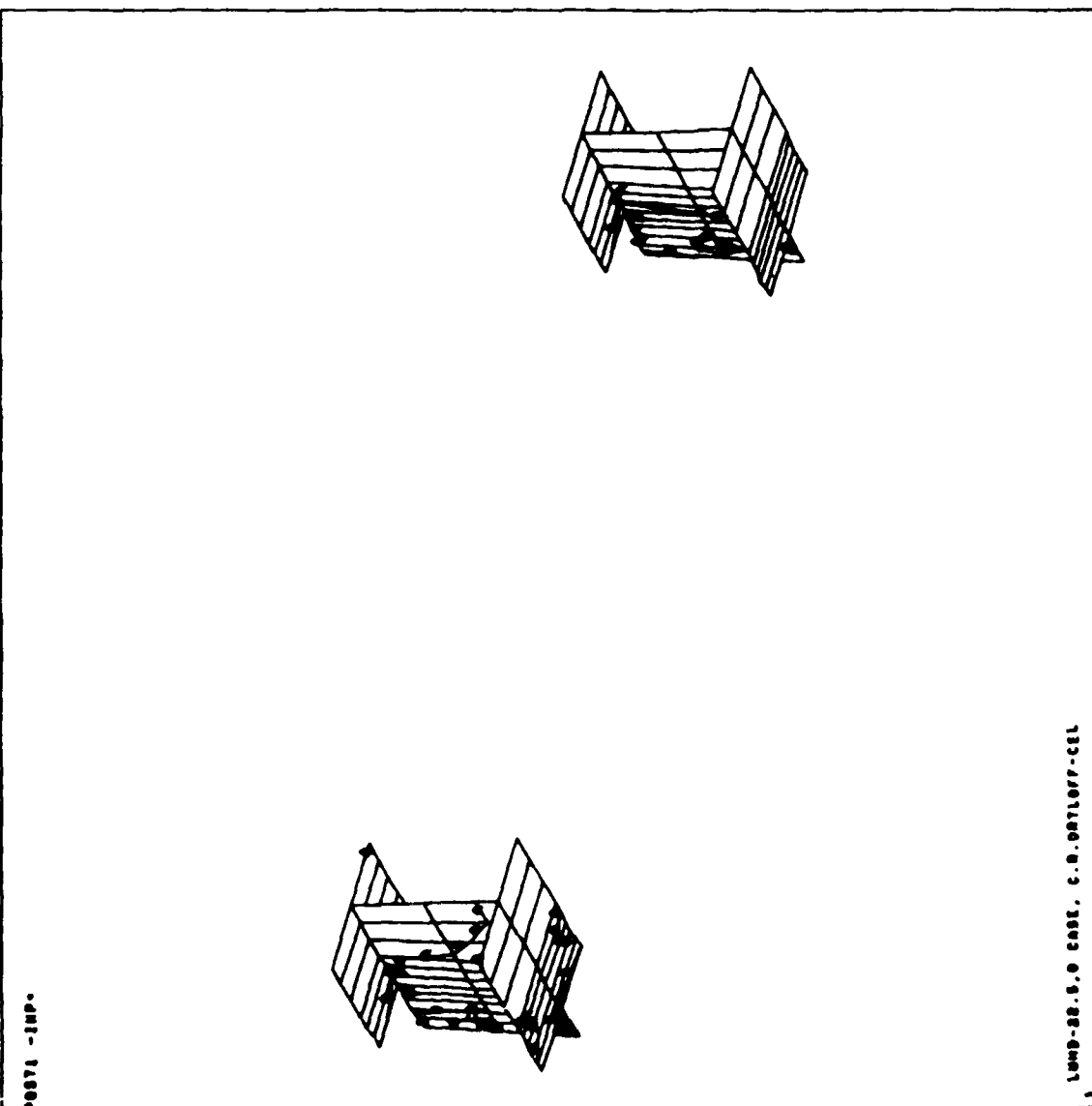


ARCS 4.00
 JAN 6 1987
 10130180
 POST1 STRSS
 STCD=1
 STED=1
 TIME=.010
 STOE
 TOP
 ZOOM
 XU=-1
 YU=-1
 ZU=1
 DIS1=31.0
 XP=93
 YP=32.6
 ZP=-3.5
 XRT0=1.06
 YRT0=1.48
 MIDEN
 MX=19343
 MY=2136
 A=8004
 B=7872
 C=10740
 D=13600
 E=10476



GIMBAL
 CORNER
 SUPPORTS

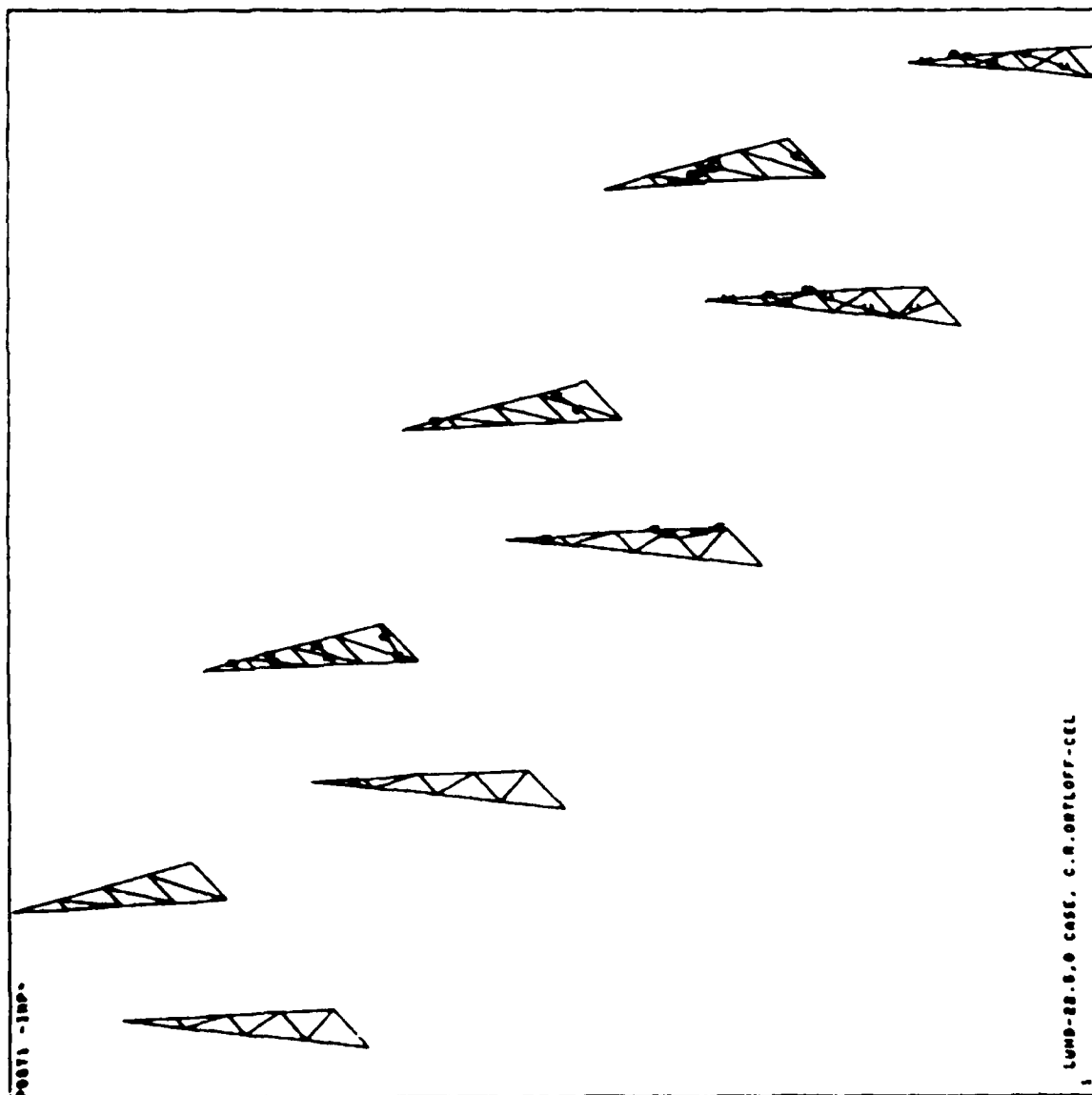
ANSYS 4.20
 JAN 6 1987
 10134146
 POST1 STRESS
 STEP=1
 1720=1
 TIME=.010
 SLOC
 700
 2004
 RU=1
 VU=1
 20=1
 0107-03.0
 RF=66.8
 VF=14.6
 ZF=18.6
 RT0=1.06
 VT0=1.48
 M100EN
 M1=134306
 M2=1100
 A=23207
 B=46607
 C=67767
 D=89907
 E=118107



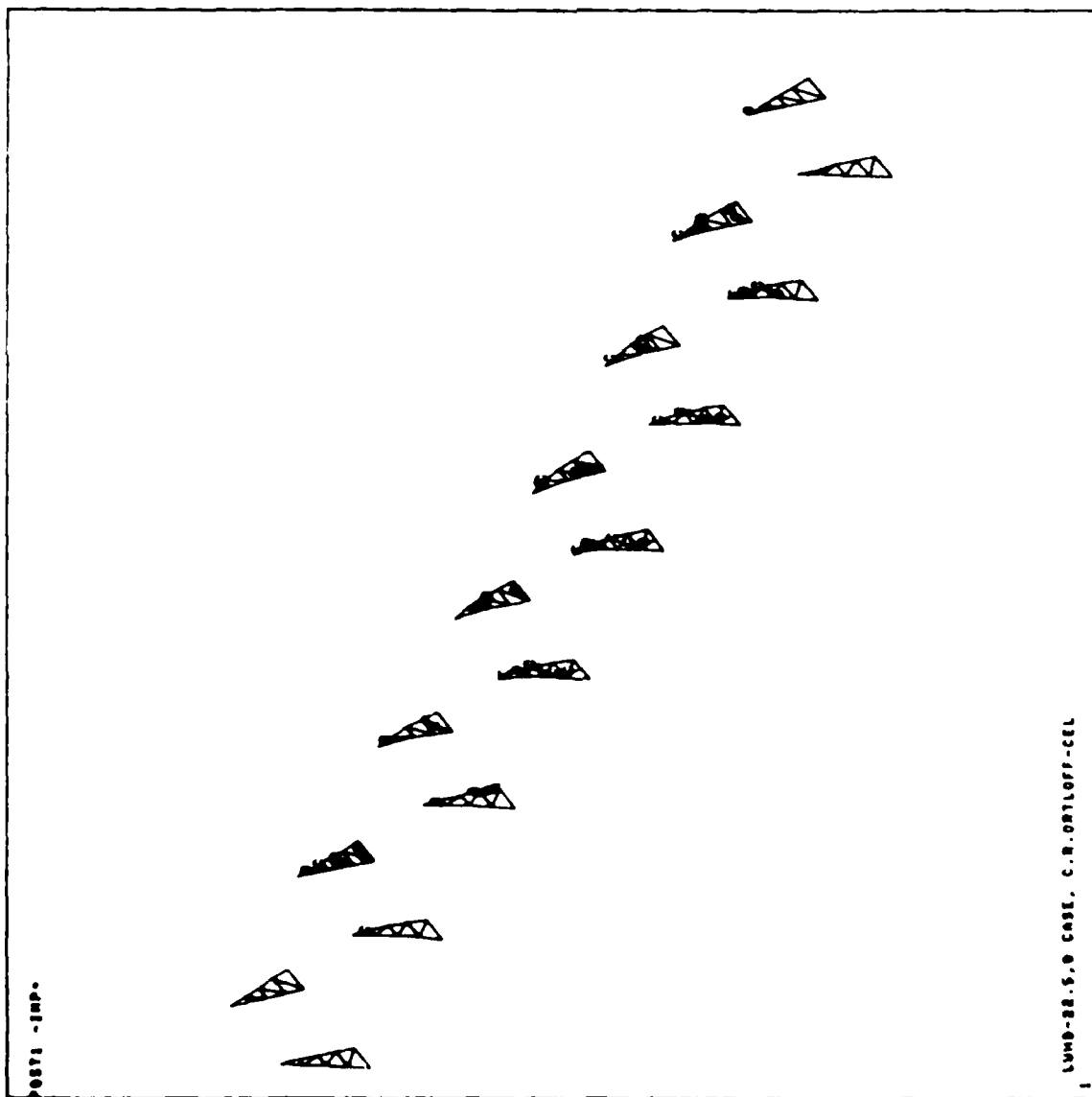
0991-1000

LUNN-22.6.0 CASE, C.A. ONYLOFF-CAL

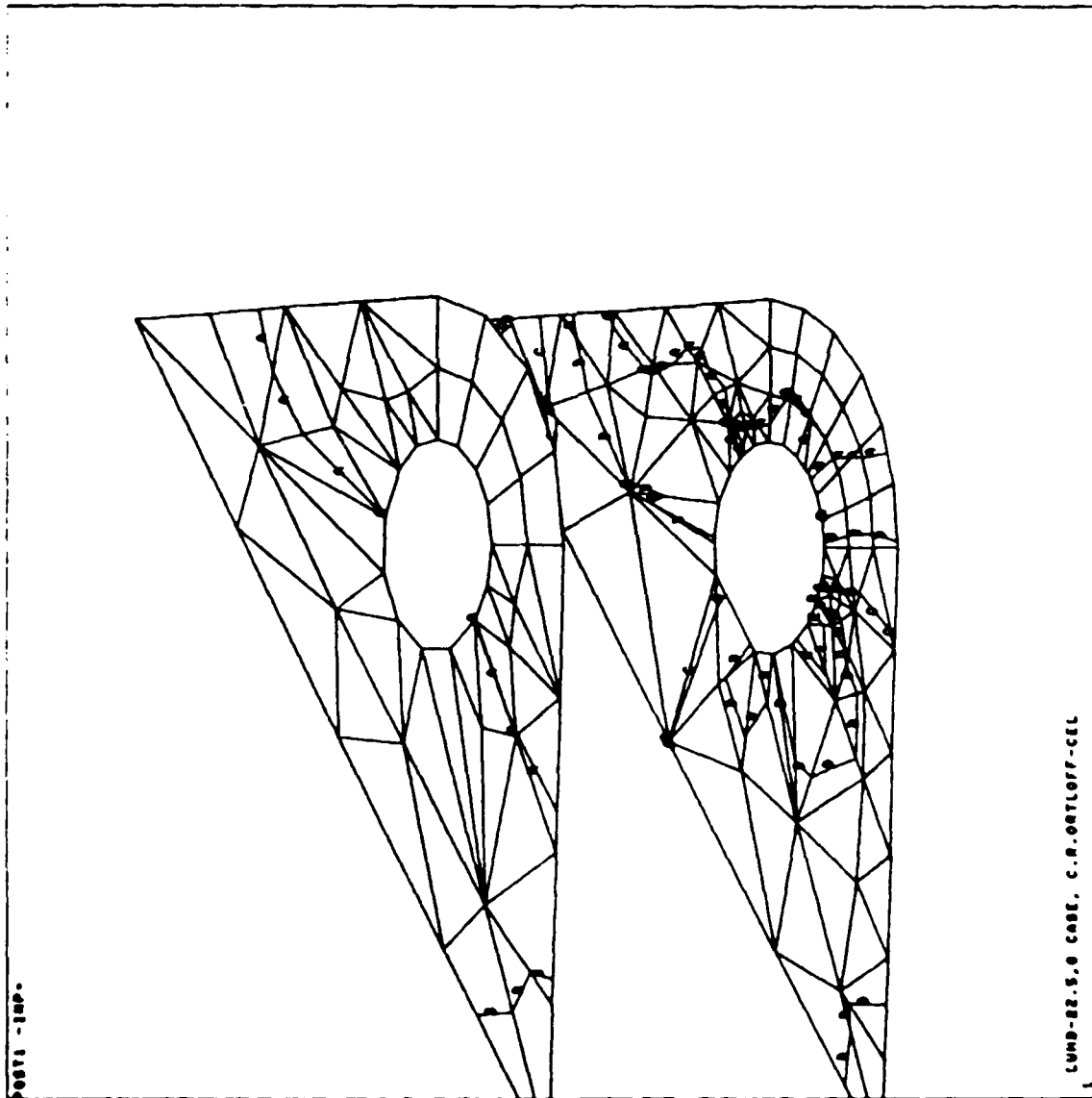
ANSYS 4.20
 JAN 6 1987
 10:04:18
 POST1 STRESS
 SECP-1
 ETEN-1
 TIME-.010
 SLOC
 TOP
 ZOOM
 ZN=-1
 VU=-1
 ZN=1
 S 107-24.3
 S 17-34.8
 S 17-11.7
 S 17-6.48
 V870-1.42
 H100EN
 RE-70200
 RE-1572
 A-13672
 B-25070
 C-20200
 D-50506
 E-62004



GROVS 4.88
 JAN 6 1967
 10:24:24
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.010
 SLOC
 TOP
 NV=-1
 VU=-1
 ZU=1
 DIST=45.8
 XF=82.8
 YF=3.55
 ZF=3.7
 HIDDEN
 MX=75100
 MY=1376
 M=13072
 D=85870
 C=30208
 B=50586
 E=62864



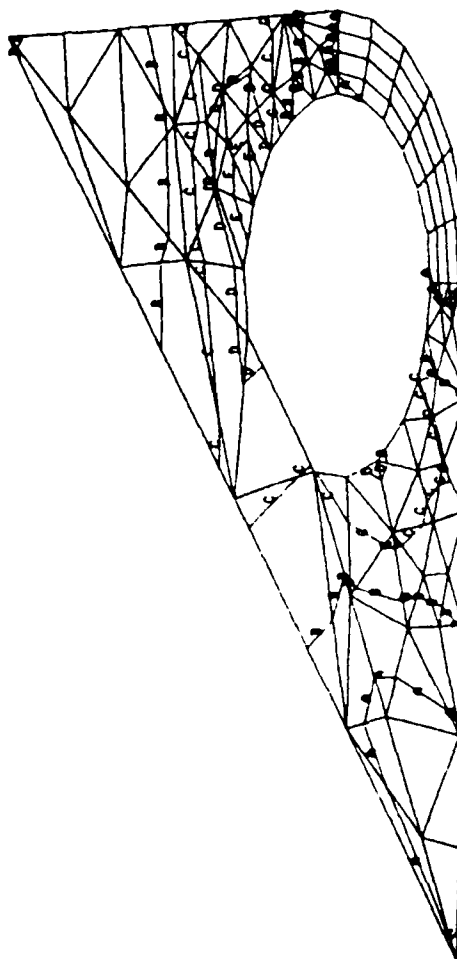
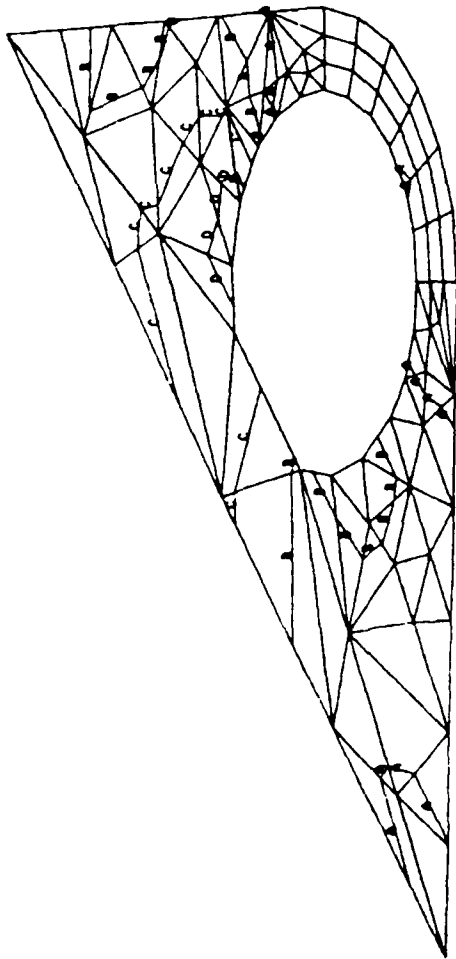
ANSYS 4.20
 JOB 8 1987
 10/21/87
 POST1, STRESS
 STEP=1
 ITEM=1
 TIME=.010
 SEQ
 TOP
 ZOOM
 XU=1
 YU=1
 ZU=-1
 3 0187-0.57
 4 0641.8
 5 0648.8
 6 27-6.98
 7 0870-1.82
 8 0870-1.08
 MIDDLE
 MZ=18831
 MM=605
 A=2888
 B=6730
 C=9809
 D=18379
 E=18948



TOP TABS

ANSYS 4.20
 JAN 6 1987
 10:10:32
 POST1 SYBSS
 STEP=1
 ITER=1
 TIME=.010
 SICE
 TOP
 ZOOM
 XU=1
 YU=1
 ZU=-1
 Z DIST=9.00
 Z XF=61.7
 Z YF=13.4
 Z ZF=-9.50
 XRT0=1.22
 MIDDEN
 MM=49712
 MM=1515
 A=8780
 B=16974
 C=25150
 D=33344
 E=41520

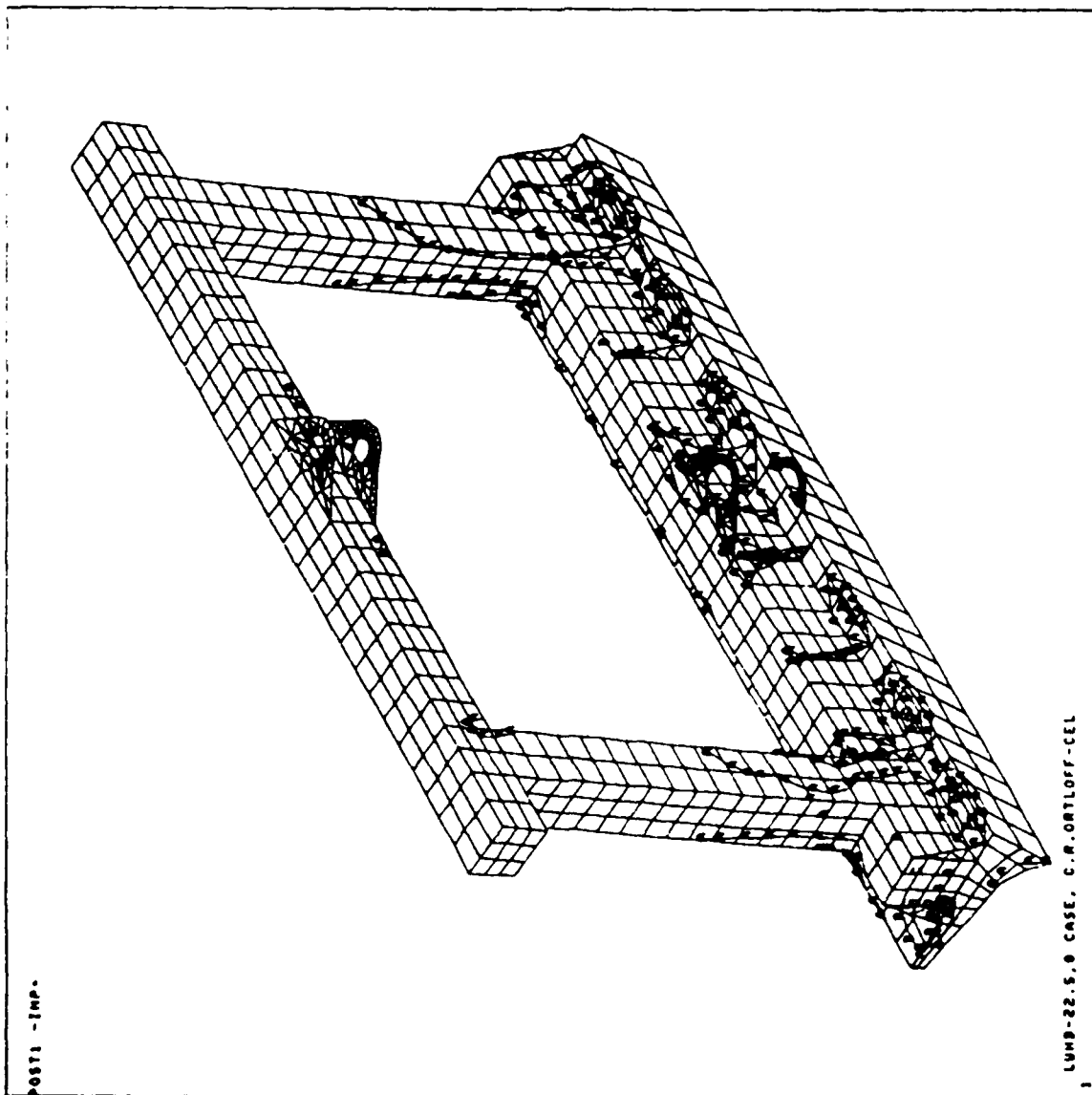
POST1 -IMP.



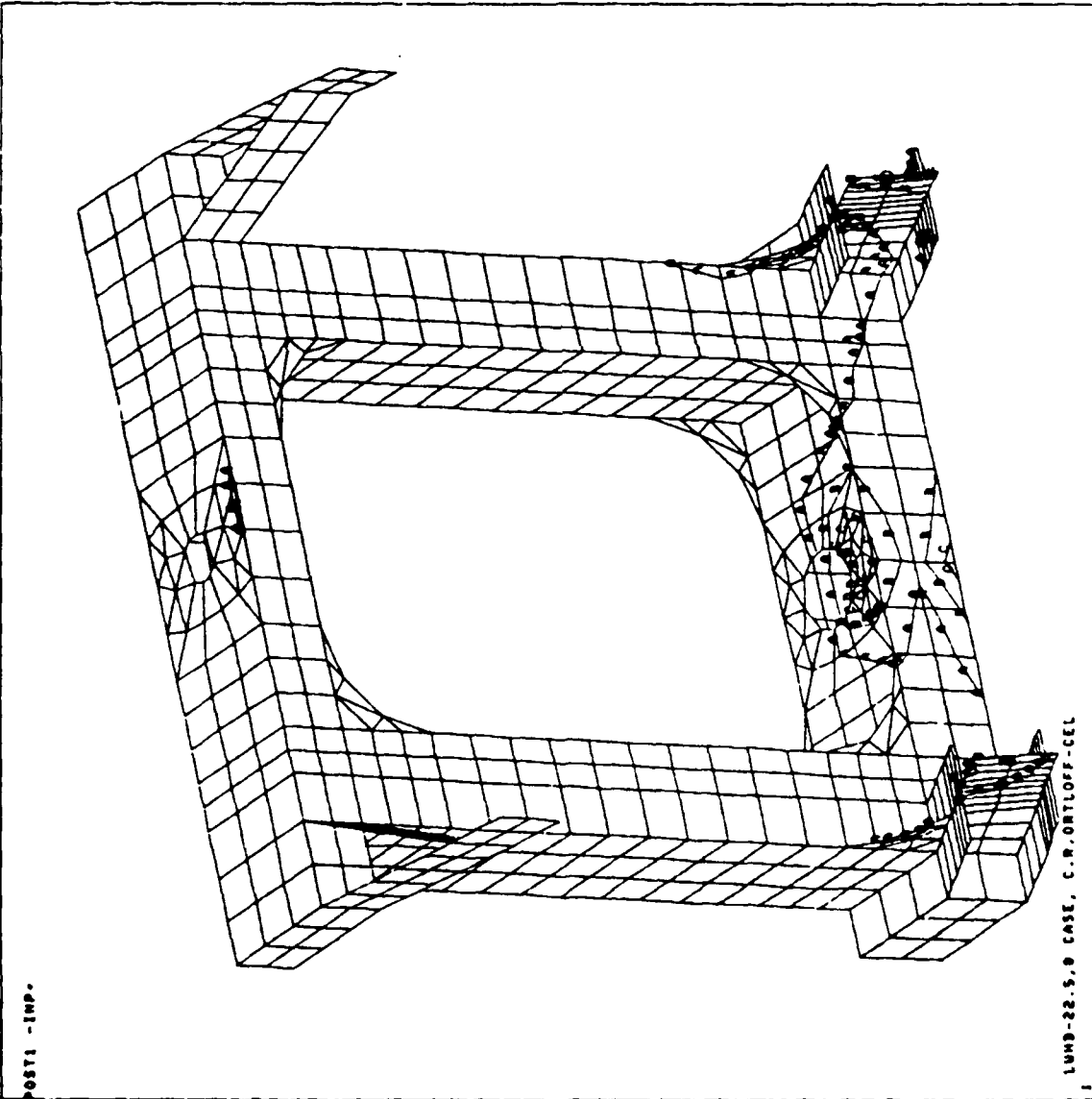
LUMB-22.5.0 CASE, C.R.ORTLOFF-CEL

BOTTOM TABS

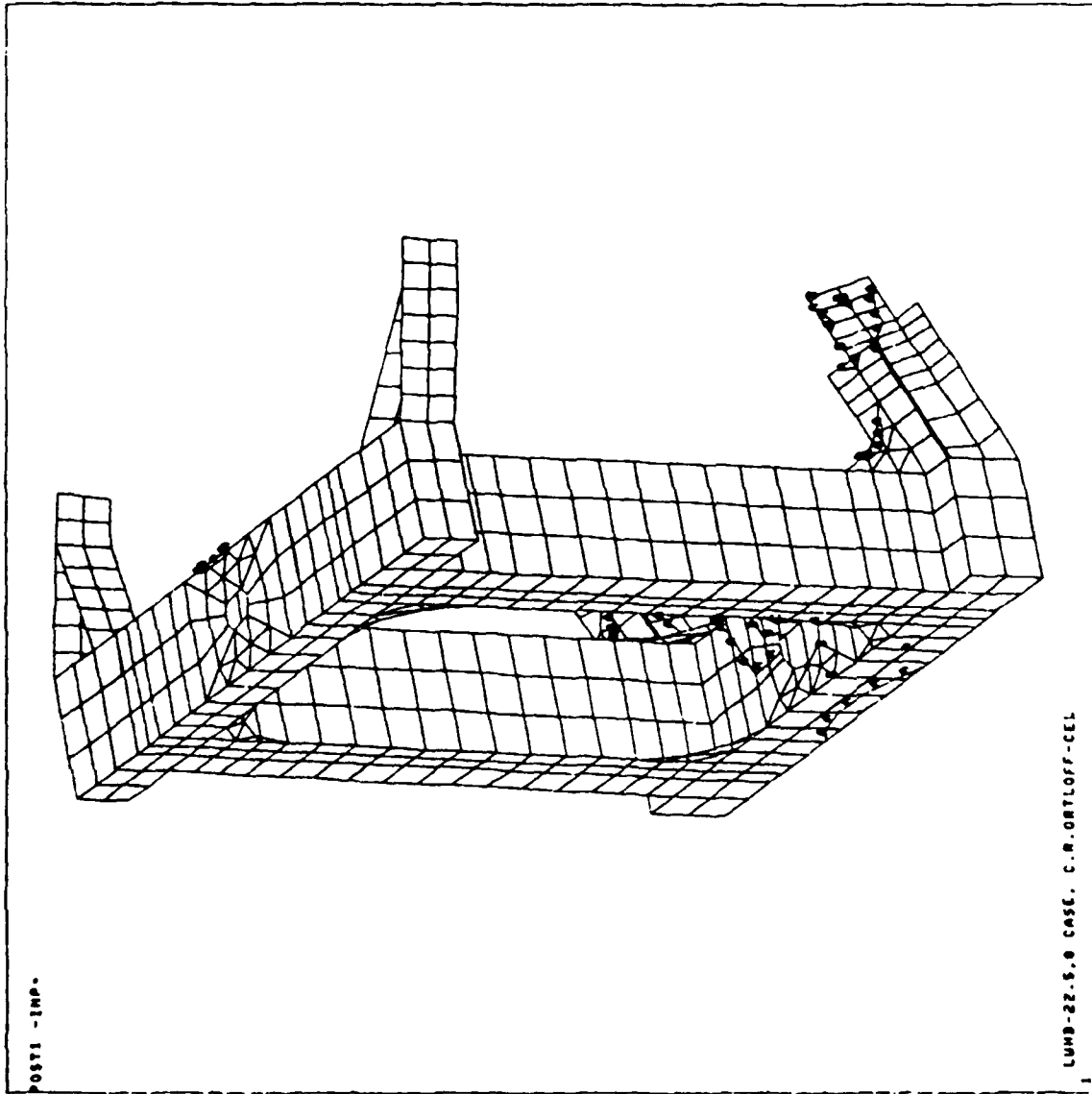
ANSYS 4.20
 JAN 6 1987
 10100130
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.010
 SLOC
 TOP
 NU=1
 VU=1
 ZU=-1
 B157-58-2
 XF-54-2
 YF-26-4
 ZF-4-85
 MIDDEN
 MX-127580
 MY-605
 A-21767
 B-42030
 C-84003
 D-85266
 E-106418



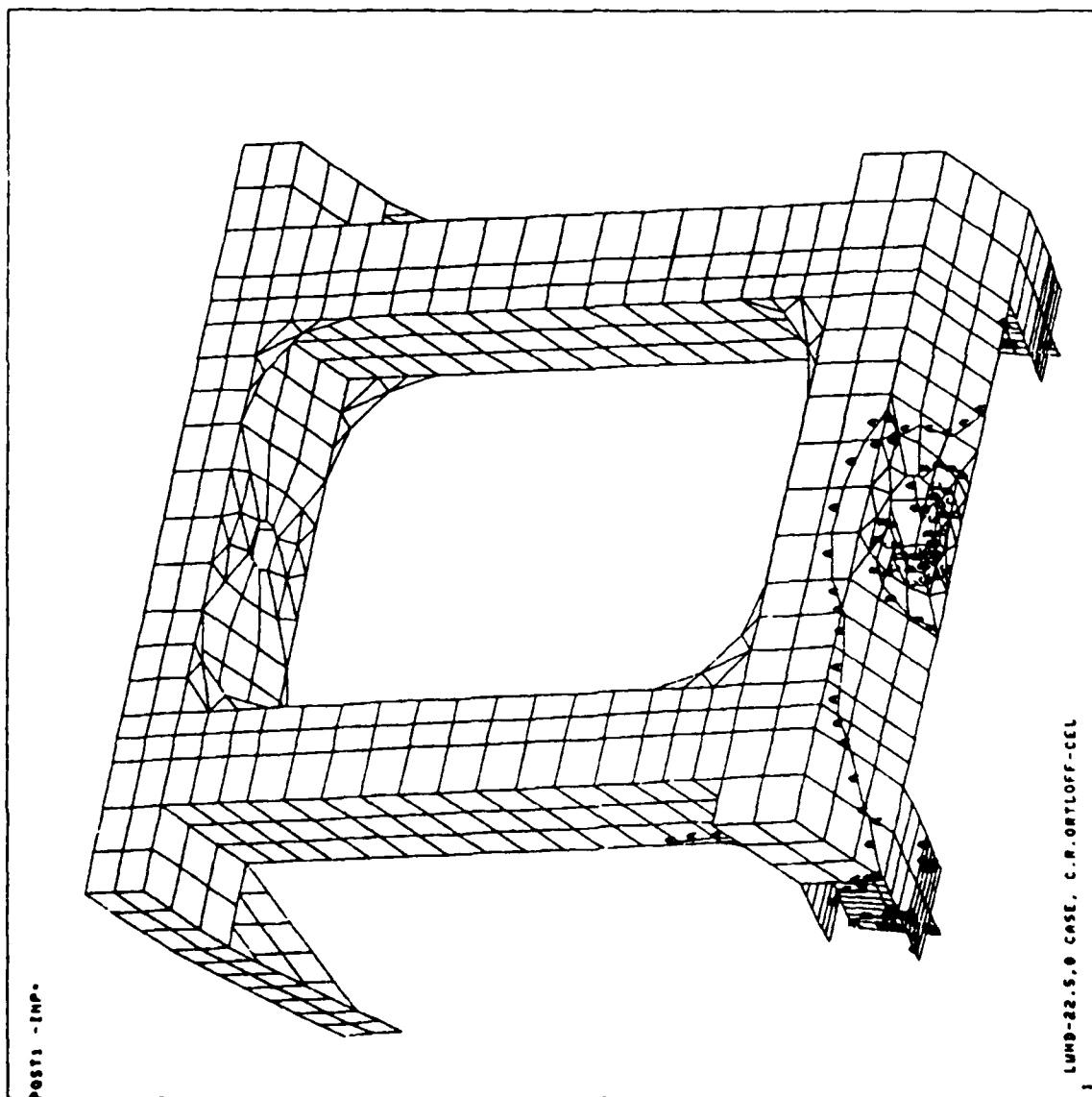
ANSYS 4.23
 JAN 6 1987
 10104137
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.010
 SLOC
 TOP
 XU=1
 VU=1
 ZU=-1
 DIST=28.7
 XF=63.9
 VF=35
 ZF=-7.93
 HIDDEN
 MX=155305
 MY=448
 A=26257
 B=58867
 C=77877
 D=103687
 E=188487



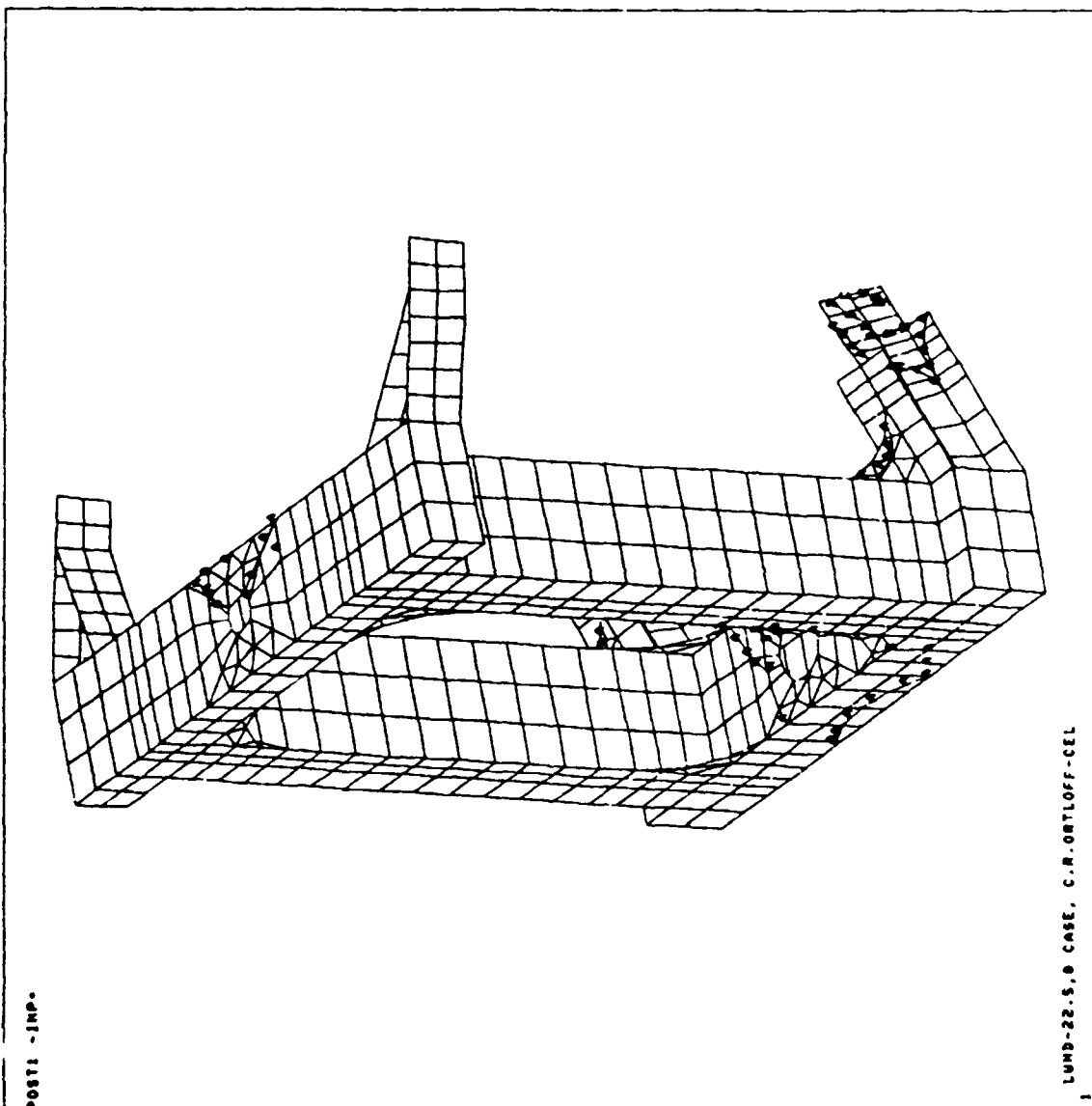
ANSYS 4.20
 JAN 6 1987
 8:56:12
 POST1, STRESS
 STEP=1
 ITER=1
 TIME=.018
 SLICE
 TOP
 NU=1
 VU=1
 ZU=1
 DIST=34.9
 XF=57.3
 YF=23.9
 ZF=-7.62
 HIDDEN
 MX=155205
 MY=448
 MZ=26257
 D=52067
 C=17877
 B=102687
 E=129487



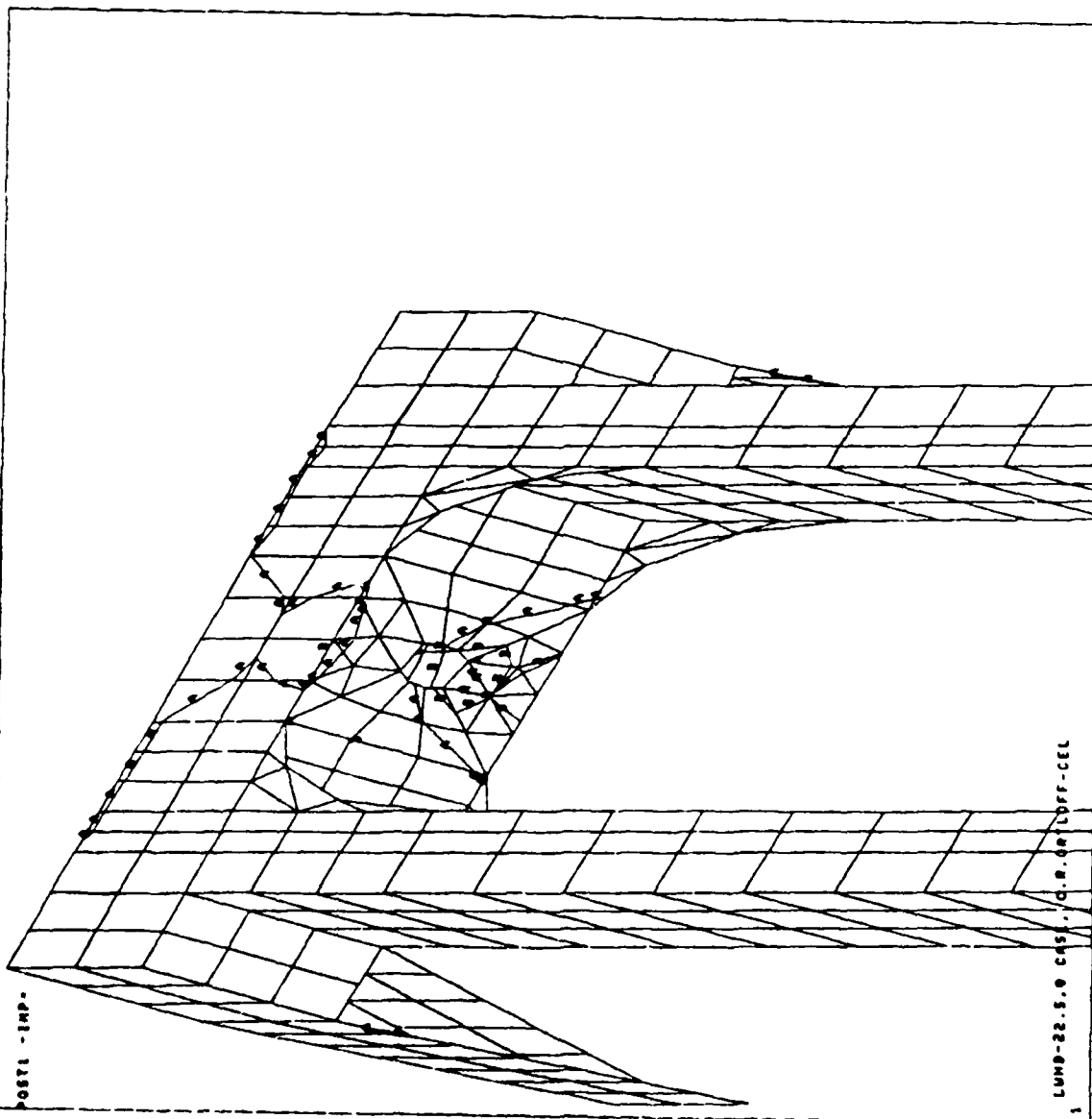
ANSYS 4.20
 JAN 6 1987
 10:01:00
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.010
 SLOC
 TOP
 NU=-1
 VU=-1
 ZU=1
 DIST=20.7
 MF=63.9
 VF=35
 ZF=-7.93
 MIDDLE
 MK=155305
 MN=448
 N=26257
 D=52067
 C=77877
 D=103687
 C=129487

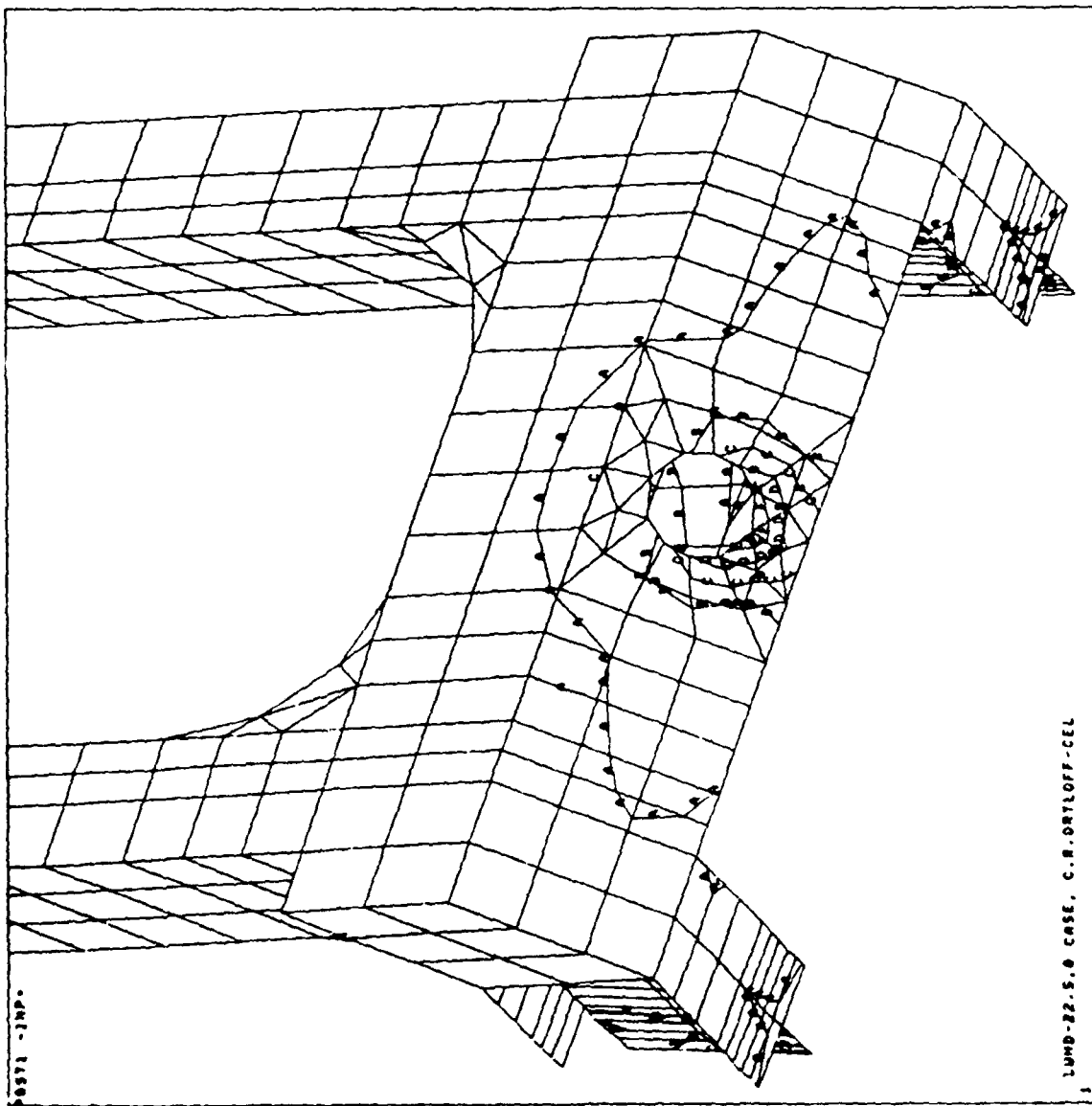


ARSYS 4.20
 JAN 6 1987
 14128117
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.081
 SICE
 TOP
 XU=1
 VU=1
 ZU=1
 DIST=34.9
 XF=57.3
 YF=32.8
 ZF=7.62
 MIDDEN
 RK=178685
 RM=756
 A=28077
 B=57389
 C=85721
 D=114043
 E=142365



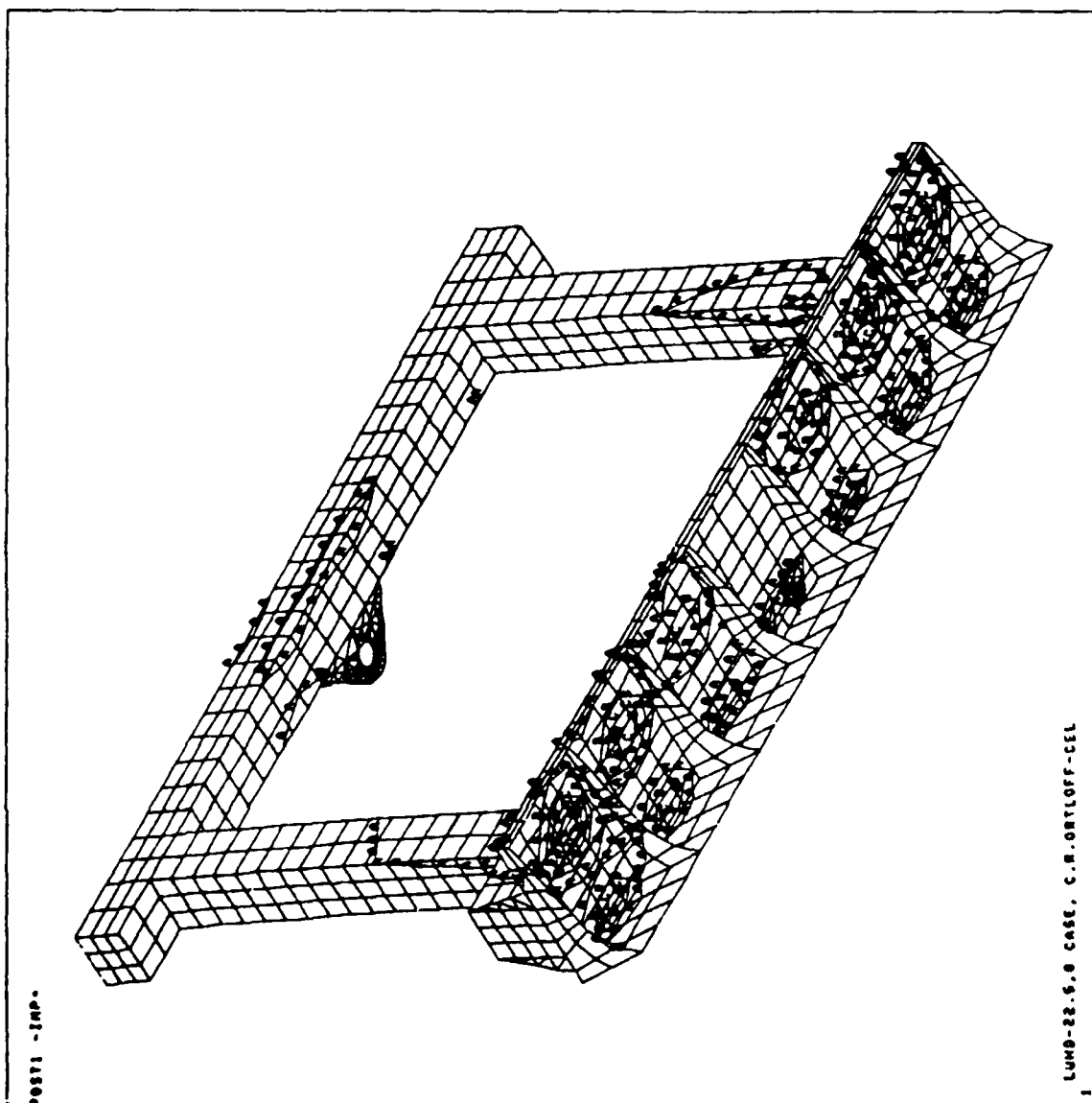
ANSYS 4.20
 JAN 6 1987
 14110164
 POST1 STRSS
 STEP=1
 ITER=1
 TIME=.081
 SIZE
 TOP
 ZOOM
 ZU=-1
 ZV=-1
 ZW=1
 4 DIST=33.8
 5 XF=53.7
 6 YF=45.4
 7 ZF=2.27
 VRT0=2.63
 HIDDEN
 MX=43536
 MY=0
 A=16200
 B=31649





ANSYS 4.20
 JAN 6 1987
 14101.05
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.001
 SICE
 TOP
 ZOOM
 XZ=1
 YZ=1
 ZU=1
 BIST=22.0
 ZF=53.2
 VF=15
 ZF=7.5
 VRTO=1.67
 HIDDEN
 RX=17000
 RM=0
 A=20077
 B=57300
 C=85721
 D=114043
 E=142366

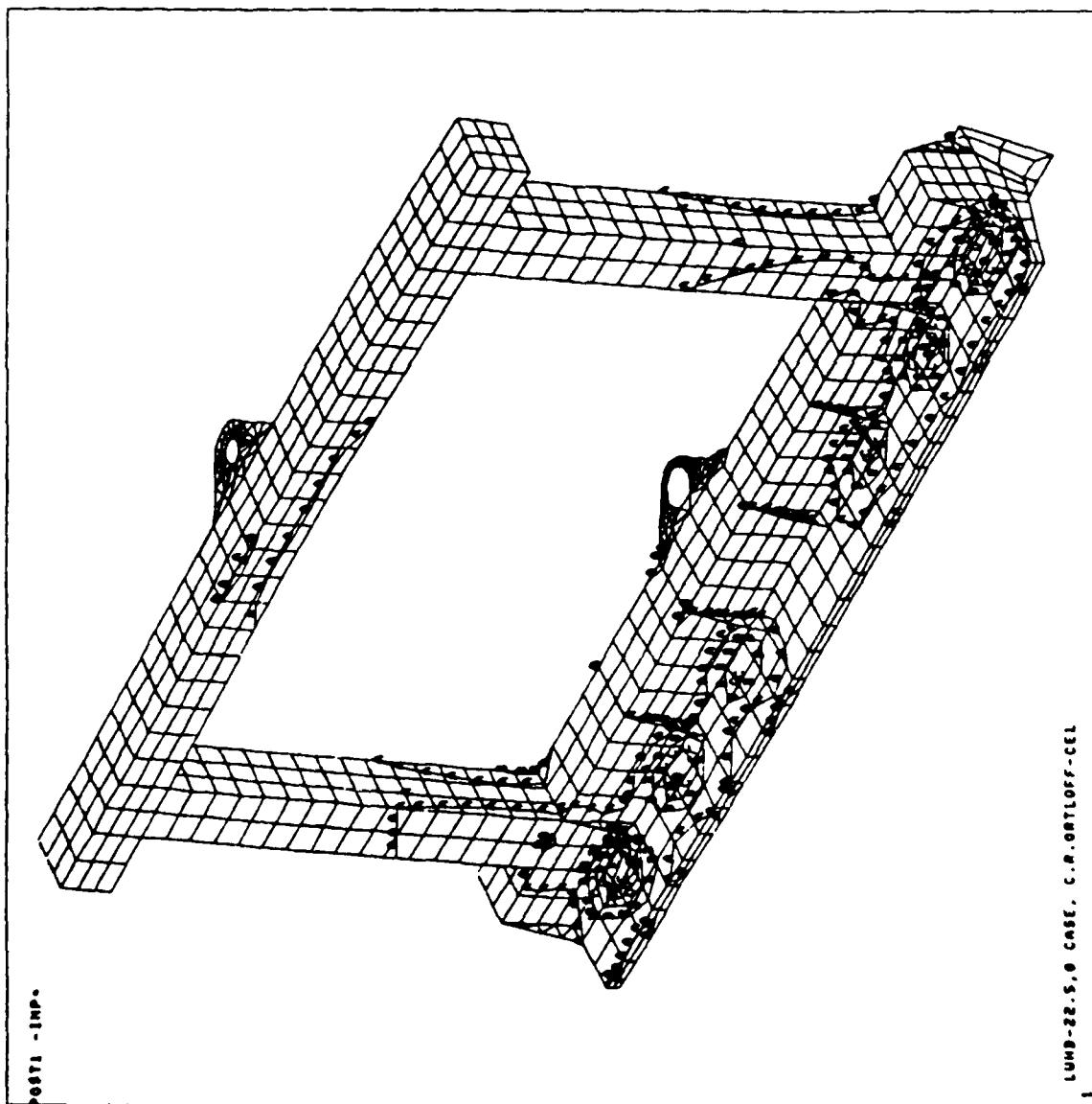
ANSYS 4.20
 JAN 6 1987
 13:38:59
 POST1 STRESS
 STEP=1
 TIME=1
 TIME=.001
 SIZE
 TOP
 KU=-1
 YU=-1
 ZU=-1
 4 DIST=58.2
 8 KF=54.8
 5 VF=25.4
 27=4.85
 HIDDEN
 RM=132034
 RM=507
 A=22427
 B=44349
 C=66271
 D=88193
 E=110115



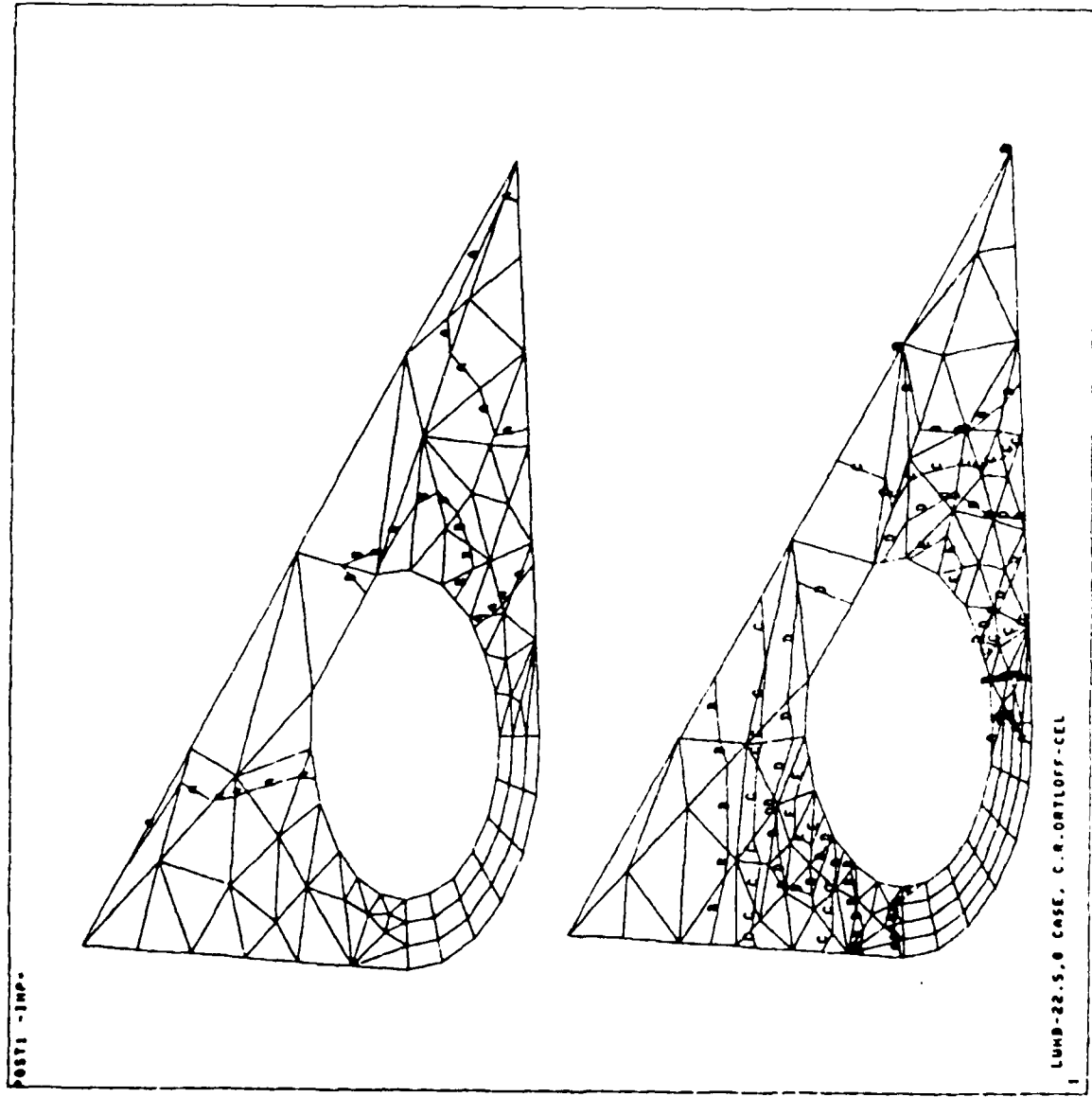
POST1 -IMP-

LUND-22.5.0 CASE, C.M.ORTLOFF-CEL

ANSYS 4.20
 JAN 6 1987
 14119118
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.001
 SLOC
 TOP
 KU=1
 VU=1
 ZU=1
 DISP=56.6
 XF=51.2
 YF=27.3
 ZF=4.17
 MIDDEN
 RN=138034
 RM=607
 A=82427
 B=44349
 C=66271
 D=88193
 E=110116

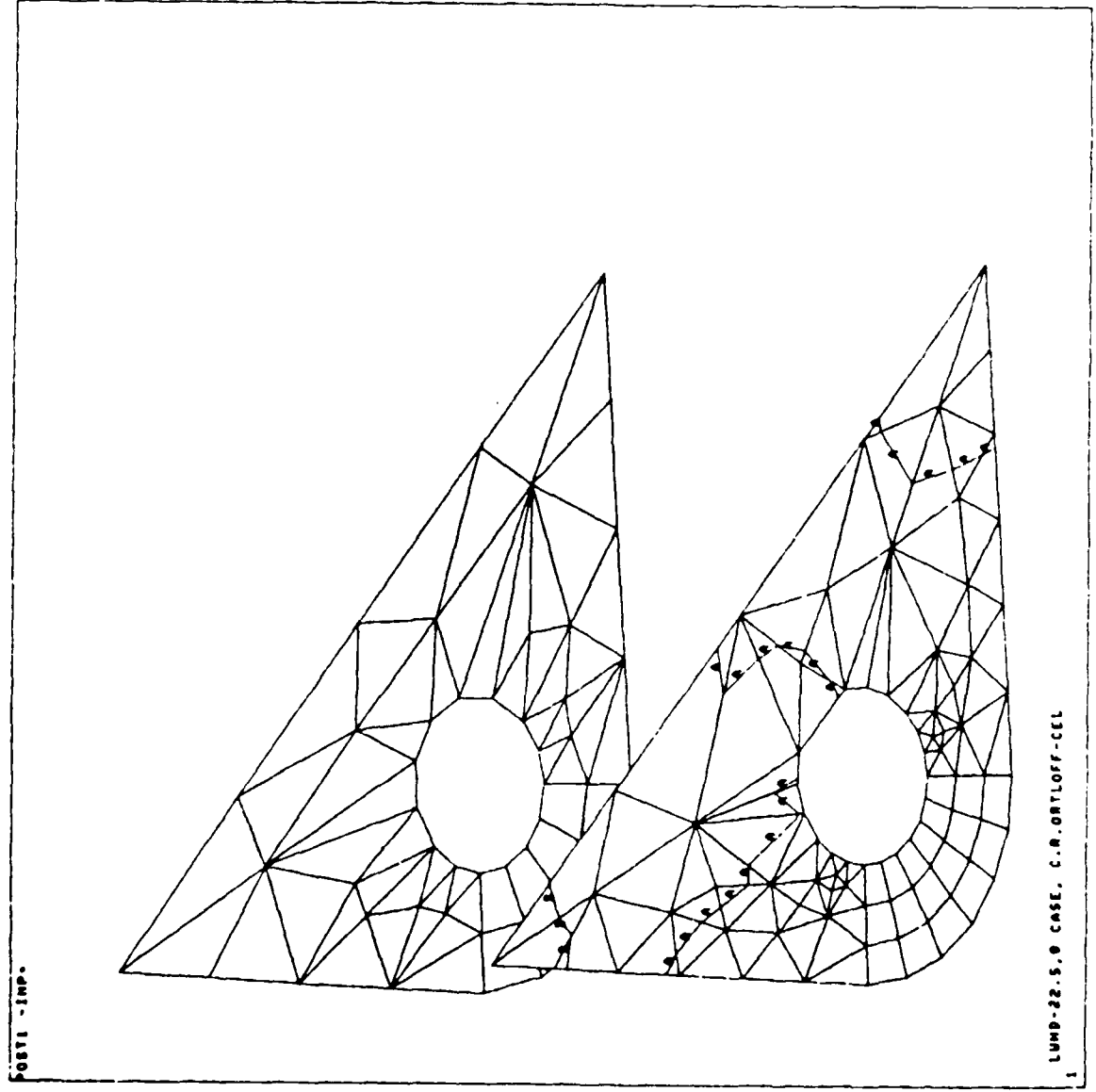


AREVS 4.20
 JAN 6 1987
 1973746
 POST1 STRESS
 STEP=1
 ITER=1
 TIME=.001
 SLOC
 TOP
 ZOOM
 KU=-1
 VU=-1
 ZU=-1
 9 DISP=7.72
 9 XF=62
 9 VF=13.3
 9 ZF=-9.37
 KNT0=1.04
 MIBEN
 MX=47211
 MY=507
 A=8881
 B=16075
 C=23858
 D=31643
 E=38427



BOTTOM TABS

ANSYS 4.20
 JAN 6 1987
 14726716
 POST1 STRESS
 STEP=1
 LAYER=1
 TIME=.001
 SIZE
 TOP
 ZOOM
 KU=-1
 VU=-1
 ZU=-1
 * BIST=0.65
 * KF=43.6
 * VF=40.5
 * ZF=0.36
 XRT0=1.04
 VRT0=1.28
 MIDDLE
 RE=18079
 MM=980
 A=0291
 B=16075



TOP TABS

AD-A183 993

LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR PHASE 1 AND
PARTIAL PHASE 2 VOLUM (U) FMC CORP MINNEAPOLIS MINN
NORTHERN ORDNANCE DIV R RATHE ET AL APR 87

5/5

UNCLASSIFIED

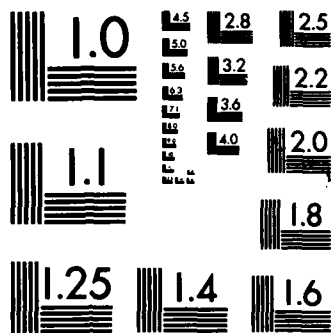
FMC-E-3041-VOL-D3-PT-1

DAAA21-86-C-0047

F/G 19/6

NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

END

10-87

DTIC